Essays in industrial organization and management strategy

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Essays in Industrial Organization and Management Strategy

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PROEFSCHRIFT

ter verkrijging van de graad van doctor aan de Katholieke Universiteit Brabant, op gezag van de rector magnificus, prof. dr L.F.W. de Klerk, in het openbaar te verdedigen ten overstaan van een door het college van dekanen aangewezen commissie in de aula van de Universiteit op

vrijdag 26 april 1996 om 16.15 uur

door

Paul Wilhelmus Johannes de Bijl

geboren op 29 december 1967 te Nuenen.

Promotoren:

prof. dr H. Bester
prof. dr E.E.C. van Damme

Ter herinnering aan mijn vader, Jan de Bijl

Le temps est assassin

(Véronique Sanson)

Contents

Preface

This thesis was written while I was a student in the European Doctoral Program ENTER, with my roots at the CentER for Economic Research, Tilburg University. I started in May 1992, and spent the academic year 1993-1994 at GREMAQ, Université de Toulouse I.

Five essays in the theory of industrial organization and management strategy constitute the body of this dissertation. It is obvious that strategic behavior of firms and the internal organization of firms are important issues. It is also obvious that managers should master practical aspects of strategy and organization. Now one may ask: why do we need theory? One answer is that it helps to ask the right questions in a complex world. Understanding how things work can help managers cope with complexity and uncertainty.

I have acquired faith in the raw power of stripping away distracting details from real-life problems. Although strategies are often gradually (and sometimes implicitly) developed by crafting, re-crafting, and adapting to changing circumstances, I believe that there are gains from combining the intuitive and adaptive aspects of strategy with logic and rigor.

Organization of the thesis

The essays in this dissertation are in the same field, but not on the same topic (except chapters 4 and 5, which are more closely related).

Chapter 1, the introduction, is meant for a wide audience. It gives a flavor of industrial organization, game theory, and management strategy. Since the main part of this book may be bewildering to non-specialists, I have tried to make the main ideas clear and accessible to people with a broad interest in strategy and organization. To do this, chapter 1 presents the essays as fictitious cases.

Chapter 2, "Moral Hazard and Noisy Information Disclosure," was the first project for my dissertation. Chapter 3, "Entry Deterrence and Signaling in Markets for Search Goods," was also initiated during 1992. A previous version of this paper was selected winner of the 1994 Young Economists' Essay Competition Award of the European Association for Research in Industrial Economics (EARIE). It has been accepted for publication in the *International Journal of Industrial Organization.* The main research for chapter 4, "Delegation of Responsibility in Organizations," and chapter 5, "Strategic Delegation of Responsibility in Competing Firms," was done during my stay in Toulouse. When I came back to Tilburg in the summer of 1994, I started to work on chapter 6, "Aftermarkets: The Monopoly Case." A summary in Dutch concludes.

Thank-yous

No man is an island. The research that led to this dissertation has benefited tremendously from the help of many people.

I had the privilege of being supervised by Helmut Bester, Eric van Damme, and Jean Tirole. They did not only teach me economics, but also how important it is to be critical and pose the right questions. As an illustration I recall what one of them asked me after having listened to some of my rash ideas for the umpteenth time: "*Quelles sont les bonnes questions?*". It is a great pleasure to express my gratitude to them.

Besides my supervisors, I wish to thank the other members of the PhD Committee: Patrick Bolton, Sytse Douma, Chaim Fershtman, and George Hendrikse. Thanks are also due to my former teachers at Erasmus University Rotterdam, Sanjeev Goyal and Dan Kovenock, for introducing me to research in industrial organization. Jacques Crémer, for whom my name turned out to be the ultimate tongue-twister, was extremely kind and helpful in organizing my stay in Toulouse.

Many other people have been very kind to discuss my work with me. Thanks are due to all of them. Among these people are (I am sure that the following list is incomplete): Philippe Aghion, Andreas Blume, Jan Bouckaert, Juan Carrillo, Jai Pil Choi, Charles Corbett, Xiangzhu Han, In Ho Lee, Sjaak Hurkens, Jos Jansen, Christopher Kilby, Peter Klibanoff, Boris Maurer, Bert Meijboom, Erik van de Poel, Jean-Charles Rochet, Joris Scheepens, Roland Strausz, Frank Verboven, Celeste Wilderom, and several participants of the CEPR European Summer Symposium in Economic Theory 1995 at Gerzensee, Switzerland.

More formal discussions about my research took place during presentations and also via the refereeing processes of academic journals. I wish to thank seminar participants at CentER, GREMAQ and IDEI at Université de Toulouse I, Katholieke Universiteit Leuven, Universiteit van Amsterdam; conference participants of the AIO Presentatiedag '94 at Tilburg, the EARIE '93 Conference at Tel Aviv (Israel), the EARIE '94 Conference at Chania (Greece), the ENTER Jamboree '94 at Ladenburg (Germany), the ESEM '94 Congress at Maastricht, the 7th World Congress of the Econometric Society at Tokyo (Japan); Raymond De Bondt and Joseph Harrington, Jr. as editors; Harold Houba and Michael Waterson as discussants; and anonymous referees of various journals.

Of course, I am grateful to all the people at CentER, GREMAQ, and IDEI for creating stimulating and very pleasant research environments. Their support has been crucial in many ways. Since *les joies de la vie* are so pronouncedly present in Toulouse and its surroundings, I would almost go so far as to thank the mayor of Toulouse as well, but I do not think that he will ever read this.

In order to visit conferences, one has to find ways to finance logistic services provided by airlines, railway companies, and hotels. I gratefully acknowledge financial support by CentER, CEPR, EARIE, Econometric Society, ENTER, the Erasmus Programme, NWO, and

Shell Nederland B.V.

Among my friends, some hardly had a clue about what I was doing, while some of those who did, pretended that they didn't. Henk-Arnold Sijnja, I am still wondering to which category he belongs, used to address my (former) employer as the Center for Economic Surgery... Anyway, my friends, and also my brother Roel and his wife Birgit, were always interested in my wanderings. This is also a good place to express my appreciation to Alexander Ramselaar and Roel for accepting the task of supporting me as *paranimfen* during the PhD defence.

I extend special thanks to my mother. Together with my father, she provided an invaluable and solid foundation that enabled me to pursue my studies. Despite the illness of my father, both of them encouraged me to grasp the opportunity to do research in Toulouse. I have always been convinced that it was the right thing to do – although the beginning was difficult.

Finally, I wish to thank Denise for her encouragement and support.

Tilburg, February 1996

Chapter 1

Introduction

1.1 Introductory Remarks

The aim of this chapter is to present the research that I carried out to a wide audience. It also offers those trained in theoretical industrial organization an alternative entry to the essays.

This book has its roots in theoretical industrial organization. The theory of industrial organization makes heavy use of techniques developed in game theory. In each essay, I use a game-theoretic model to analyze a specific, well-defined problem. Section 1.2 explains briefly what game theory and industrial organization are about, and argues why these fields may be interesting for management strategy and vice versa. Sections 1.3-1.7 informally present the essays that constitute this dissertation. Inspired by the management literature, I use fictitious cases that illustrate the strategic interactions and the basic tradeoffs. Section 1.8 concludes by discussing strengths and weaknesses of game-theoretic models in general.

1.2 About the Research

Game theory studies **strategic** or **competitive interaction** by using mathematical models.[1] "Strategic" refers to skilful planning, and the "interaction" is usually among firms in a market or individuals in an organization. A game model specifies the players in a game, the information they have (or don't have), the actions they can choose, the timing of these actions, the payoffs for each player that result from the actions that are chosen, and the preferences of the players over the payoffs (utility functions). In such a model, each player is supposed to choose actions that maximize his payoffs, given his information and his expectations about his rivals' actions.

In addition to this description of game theory, it is useful to stress the crucial perspectives of game theory on interaction. In my view, these are

The two I's:

1. **Incentives** are the driving force behind a player's actions. Predicting or explaining behavior becomes easier by figuring out "what makes someone tick."

2. **Insight** in a strategic situation (the ability to envisage various scenarios and to form expectations about other players' actions and reactions) helps a player to make smart choices. Game theory assumes that players have insight in their situation.

The perspective of the two I's enables one to anticipate reactions of rivals to a move and then to include those reactions into one's actual decision. Like in the game of chess, one explicitly thinks several moves ahead.

[1]The basic ideas of game theory without advanced mathematics can be found in, e.g., *Thinking Strategically* by Dixit and Nalebuff (1991), *Games, Strategies, and Managers* by McMillan (1992), or an article in the *Harvard Business Review* by Brandenburger and Nalebuff (1995).

The (so-called) new theory of industrial organization makes heavy use of game-theoretic models. Roughly speaking, industrial organization studies the behavior of firms and its implications for the functioning and structure of markets. The field as such initially was empirical in nature, resulting in the "structure-conduct-performance" paradigm: market structure (number of firms, product differentiation, and so on) determines behavior (prices, investment in R & D, advertising, and so on), which in turn results in performance (e.g. profits).[2] This empirical work resulted in descriptive statistics and correlations among industry variables. Because the early literature did not focus on causal relationships, it did not give much insight into the "mechanics" of markets.

Since the 1970s, industrial organization has complemented (and in some cases turned upside down) the idea that conduct comes after structure. For instance, think of firms that form a cartel in order to make it difficult for other firms to enter the market. Clearly, the cartel behavior (conduct) may determine the structure of the industry.[3] A more recent development in research in industrial organization concerns the way firms are depicted. Whereas the more traditional models view firms as profit-maximizing "black boxes," recent work develops new insights by explicitly taking into account the internal organization of firms.

Several insights of the theory of industrial organization may be important for strategic management, the research field that directly addresses problems faced by managers and often aims to offer practical advice to managers.[4] A loose definition of management strategy is the following: it is the study of the "direction of organizations, and most often, business firms. It includes those subjects of primary concern to senior management, or to anyone seeking reasons for success and failure among organizations."[5] Alternatively, management strategy is "a

[2]See e.g. Bain (1956).

[3]For a survey of the modern theory of industrial organization, see Tirole (1988).

[4]For a survey, see Spulber (1994).

[5]Rumelt, Schendel and Teece (1994), p. 9.

subset of the field of management that combines ideas about competition and organizations with lessons learned from practical business experience. It focuses on the *manager's* formulation of a plan of action to maximize the firm's expected profit by obtaining a sustainable competitive advantage for the firm."[6]

Since management strategy is not rooted in economics, but in accounting, corporate planning, and marketing, discussion between researchers in the two fields can be very fruitful in my view. On the one hand, some researchers in management strategy feel that it lacks a rigorous "backbone" that allows for formal analysis and unifying, empirical testing. Rumelt, Schendel, and Teece (1994) discuss the future of management strategy and call for a substantial increase in its (analytical) rigor. On the other hand, I believe that the insights of management strategy can help researchers in industrial organization to recognize problems that are relevant and important for business practice.

The following five sections present the fictitious cases. The discussion above, about the research fields to which the underlying models relate, is hopefully helpful to place the underlying research.

1.3 Moral Hazard and Noisy Information Disclosure

ClearCopy is a firm that produces copiers. With its present technology, production results in environmental pollution. ClearCopy's manager has to decide whether to invest in equipment that reduces pollution.

The government is an important client of the firm. Mr Jones, the civil servant who purchases copiers for governmental use, has received orders to be more favorable towards suppliers that take better care of the environment. This policy is meant to stimulate "green" behavior

[6]Spulber (1994), p. 355, emphasis in original.

by private companies.

In the past, ClearCopy considered investments to reduce pollution too costly. Recently, however, Jones wrote to ClearCopy about the new policy of the government. If ClearCopy invests, Jones will seriously consider to buy copiers from the firm. If the firm doesn't invest, Jones will start looking for alternative, "greener" suppliers. Jones's letter also said that before deciding how many copiers to buy, Jones would like to receive by mail any proofs of investment in the form of bills, so that he has "hard" (i.e., verifiable) information about ClearCopy's investments (if any).

The game is as follows. ClearCopy decides whether to invest in green production, and whether to inform Jones when it invests. The firm's investment decision cannot be observed by the government; it is a **hidden action**. If the firm sends information to the government, it is not certain that it will be received; **noise** hampers the transmission of information. Based on his information (either hard information or nothing), Jones decides whether to buy from ClearCopy. Because of time pressure, he will not give ClearCopy a second chance if he receives no evidence.

A possible source of the noise is that bureaucracy may postpone the delivery of mail. Alternatively, letters may get stuck or even lost in the mail system. Another interpretation of the noise is that due to work overload, Jones can pay attention to only a fraction of the information he receives.

A crucial assumption in this example is that there are **complementarities**. If the government learns that ClearCopy invested, it will adopt a favorable purchasing policy towards ClearCopy. Both the government (which is assumed to value a clean environment) and the firm are then better off.

It is instructive to look briefly at two extreme cases.

- **Communication impossible:** Assume that Jones cannot receive any mail and has to rely on his expectations about Clear-

Copy's investment. Then the firm does not have an incentive to invest in a cleaner production process. To see this, notice that ClearCopy's investment decision cannot be communicated to Jones. Therefore, Jones's purchase decision does not depend on the firm's *actual* behavior, but on *expectations about* behavior. ClearCopy can then just as well not invest. If Jones foresees this he will directly look for alternative suppliers.

- **Perfect communication:** Now suppose that mail always reaches Jones so that there are no obstacles in informing the government. Investing, which is now profitable with certainty, will take place. Jones receives the evidence and will be eager to buy from ClearCopy.

With the outcomes of these extreme cases in mind, let's move to the intermediate case of noisy communication. Both ClearCopy and Jones are aware that any evidence that is sent to the government might get lost. Jones, if he does not receive anything, still believes that the firm *may* have invested. Because of this uncertainty, Jones can view ClearCopy's decision as if the firm chooses *randomly* between

1. investing and sending evidence to the government,

2. not investing and remaining silent.

In game theory, choosing randomly among several actions is called using a **mixed strategy**. From an equilibrium point of view one can derive that ClearCopy will act randomly. The reason is twofold. First, since investing is advantegeous, it is not optimal for ClearCopy to completely forgo this opportunity. Second, if it invests with certainty and Jones foresees this, Jones will be favorable towards ClearCopy also if he receives no evidence. But then the firm can deviate by not investing and remaining silent.

How does Jones's decision depend on the information he receives? If he receives information that ClearCopy invested, he is eager to buy from ClearCopy. If Jones does not receive information, he realizes that ClearCopy might not have invested. Jones is then less keen on buying from the firm.

If ClearCopy's manager foresees Jones's reasoning about the mixed strategy, he becomes less enthusiastic to invest compared to the case of perfect communication. This explains the title of the essay: because of the noise, there is a **moral hazard**, that is, ClearCopy's incentives to invest decrease. The reason is that if it invests and sends information to the government, it cannot be sure that Jones receives the information. If the noise is severe, the chance that the government is eager to buy will be small, even if ClearCopy invests.

Compared to the extreme case of perfect communication, the noise hurts both ClearCopy and the government. Without noise, the firm would certainly make the environmental-friendly investment and inform the government. Jones would buy and both would be better off. Consequently, both ClearCopy and Jones have an incentive to decrease or even eliminate the noise. Ways to do this are to personally deliver mail or to check whether Jones receives it. I expect that in reality this would happen if the stakes are high. Still, it may be prohibitively costly to completely eliminate noise.

The moral hazard problem is even worse when informing the government is costly. This may be the case if it takes time and effort to prepare a dossier that can be sent to Jones. Because of the involved costs, ClearCopy's incentives to inform Jones decrease further.

The main insight of this example is that noise, hindering the transmission of information, creates a moral hazard. The incentives of the first-mover (ClearCopy's manager) to commit himself to high effort decrease as it becomes less likely that information about his commitment will reach the second-mover (Jones). This was expressed by ClearCopy's strategy to choose randomly between on the one hand committing itself and informing Jones, and on the other hand shirking and remaining silent.

1.4 Entry Deterrence and Signaling in Markets for Search Goods

There is a variety of goods that are called **search goods** by economists. This means that they have quality as a search-characteristic. Fruit vendors often allow consumers to inspect fruit before buying. Stores selling audio and video equipment provide demonstrations. Automobile sellers allow consumers to perform test drives so that an assessment of quality can be made. The goods sold by the players in this fictitious case, namely cameras, can be considered as search goods. Obviously, cameras are not pure search goods. However, to avoid unnecessary complications, I abstract from the possibility that cameras may be experience goods, that is, goods of which quality is only experienced *after* purchase.

The fictitious case of this section considers two producers of high-tech goods. In the market for digital cameras, only SuperCam is active at present. Its cameras are of low quality, which is known by consumers. However, as long as SuperCam is a monopolist, it can ask a relatively high price (as high as consumers' willingness to pay for a digital camera of the given quality).

Another producer of digital cameras, Digit, has set up a store and plans to compete with SuperCam. Digit still has a market share of zero. Consumers do not know whether Digit's cameras are actually better or not than SuperCam's. One can view the quality of Digit's cameras as fixed in the short run; the quality of a camera for sale cannot be changed.[7]

To find out the quality of a Digit camera, a consumer has to visit Digit's store and try one. Imagine a consumer who is trying a Digit camera in the shop. If it is of low quality, he may not want to buy but visit SuperCam instead. However, SuperCam's store may be located

[7] A consumer may view the quality of Digit's cameras as having been determined randomly.

in another city, so that switching to SuperCam takes considerable time and effort. In that case there are non-negligable **visit costs**.[8] If visit costs are high, a consumer who finds out that Digit sells low quality may still prefer to buy from Digit even when he deplores not having visited SuperCam in the first place.

In reality, if a firm sells high quality then consumers will eventually find this out in the long run. For instance, firms can heavily advertise, attract consumers with presents, or slowly build up a reputation when consumers spread the word. Let us assume that these possibilities are ruled out, except for one possibility: a short-term price strategy.

The game is then as follows. Digit and SuperCam compete by simultaneously choosing once-and-for-all prices. Consumers observe these prices (e.g. the firms advertise), and decide which store to visit. By visiting Digit, a consumer can assess the quality of its cameras, and then decide whether to buy or visit SuperCam instead. Alternatively, by directly visiting SuperCam he will not find out Digit's quality. If the firms are interested in short-term profits, what price strategies should they choose?

Suppose that Digit's cameras are of high quality. Digit knows this, but consumers still have to find out. Can Digit convince consumers of high quality even before they visit its store? The answer is yes. A price strategy that does the job is to charge a *high price*. This works as follows. If Digit's price is high enough, consumers know that they will never buy a low-quality camera at that price. If they find out that Digit sells low quality cameras, they will prefer to visit SuperCam (if visit costs are not too high). Notice that Digit has an incentive to set a high price *only* if its cameras are of high quality. In case of low quality, Digit would charge a low price.

Summarizing, Digit can charge a high price in case of high quality, and a low price in case of low quality. This is an **informative price**

[8]In chapter 3, visit costs are called "search costs," in accordance with the convention in the economic literature.

strategy. By understanding Digit's incentives, consumers can tell by the price they observe what the quality of Digit's cameras is without having to visit its shop.

A disadvantage of the high-price strategy is that Digit cameras become expensive, which makes SuperCam cameras relatively more attractive despite their lower quality. Therefore, such a strategy is effective only if the price needed to convince consumers of high quality is not too high. Moreover, the higher the visit cost, the less likely it becomes that consumers will switch to SuperCam when they find out that Digit sells low quality. Therefore, higher visit costs result in a higher price needed to signal high quality to consumers. Thus the high-price strategy works only if visit costs are not too high. This is for instance the case if Digit's shop is located in the same town as SuperCam's, because then it is easy to switch.

Digit could possibly circumvent the problems associated with the high-price strategy by trying to decrease consumers' visit costs. This could for instance be done by locating near SuperCam's shop. By doing so, the price needed to convince consumers of high quality becomes smaller.

Charging a high price or locating close to a rival store do not perhaps seem to be smart moves. In general, consumers do not like high prices, and we expect shops close to each other to compete aggressively. However, locating close to a rival and charging a high price may be a credible signal to consumers. It tells them:

> "Digit cameras *must* be good. Visit me, with my high price and SuperCam nearby, you can easily switch to SuperCam if my cameras are of bad quality."

Now consider a twist in the example, namely that SuperCam knows the quality of Digit cameras before the firms compete in prices. Moreover, we will assume that consumers know that SuperCam is informed, and Digit knows that consumers know this. Such a situation is realistic in certain cases. For instance, SuperCam has tried Digit cameras at a trade fair, or firms have more expertise than consumers (as is often the case in markets for technically complicated products).

Again, suppose Digit sells high-quality cameras. Accordingly, SuperCam and Digit know this, but consumers are uncertain as long as they haven't visited Digit's shop. Can SuperCam use its information to keep Digit out of the market? Instead of deriving what can happen in this situation, let's *assume* that SuperCam uses its information and keeps Digit out of the market, to see whether this is a plausible situation.

Because the firms compete in prices, SuperCam can only use its information by choosing an informative price strategy. Thus, SuperCam's price if Digit sells low quality is different from its price if Digit sells high quality.

By our assumption, Digit does not attract consumers in this situation. This means that a high-price strategy does not help Digit to convince consumers that it sells high quality while at the same time attracting them to its store. As argued above, the reason must be that visit costs are relatively high, so that the high price Digit has to charge to convince consumers of high quality is too high to be attractive. Digit, however, if it foresees SuperCam's informative price strategy, can make a move to outdo SuperCam. To see this, note that if *SuperCam* uses an informative price strategy, *Digit* does not have to charge a high price to convince consumers of high quality! Because consumers can deduce the quality of Digit's cameras from SuperCam's price, Digit can grasp the opportunity to cut its price to a competitive level. The crucial observation is that SuperCam, if it wants to keep a high-quality entrant such as Digit out of the market, should not use an informative price strategy. Intuitively, SuperCam should keep Digit's informational disadvantage (recall that consumers know SuperCam's quality, but do not know Digit's quality) as large as possible.

Accordingly, SuperCam cannot use information about the quality of Digit's cameras to deter entry. To arrive at this conclusion, however, it was used that consumers know that SuperCam is informed, and that Digit knows that consumers know this.

This example demonstrates how an entrant (Digit) can choose a one-shot price strategy to convince consumers that he sells high-quality goods. Given the assumptions, however, the optimal informative price strategy (a high price in case of high quality and a low price otherwise) is effective only if consumers' visit costs are not too high. Another insight is that if an already established firm (SuperCam) is informed about the quality of an entrant's product whereas consumers are still uncertain, it cannot use this information to deter entry. The reason is that by using information about the entrant, the established firm may help the entrant to overcome its problem of convincing consumers of high quality.

1.5 Delegation of Responsibility in Organizations

In the literature on organization and management, it is well known that employees may care a lot about non-pecuniary incentives, such as job satisfaction. For instance, Dessler (1986) argues: "Few rewards are as powerful as the sense of accomplishment and achievement that come from doing a job that one genuinely wants to do [...]" (p. 254). Actually, there is a debate going on in the management literature in which performance-related pay is under heavy fire.[9] One of the basic objections is that "[...] workers are much more influenced by [...] the intrinsic interest of their work than by crass material rewards."[10] Besides that payment schemes may be costly to implement, it is put forward that they may demotivate employees.

This section is based on the assumption that a superior cannot use payment schemes to motivate his subordinate. Instead, he can appeal

[9] See e.g. Kohn (1993) and the references therein.

[10] *The Economist* (1994a), p. 69.

to the subordinate's **private benefits**, such as job satisfaction and the acquisition of professional experience. This can be done by delegation of responsibility.

We will see that empowering a subordinate requires commitment on behalf of the superior. In particular, it is important that the manager communicates the seriousness of his intent and curbs a tendency to overcontrol the detail, that is, it is important not to oversupervise.[11] In other words, delegation works only if management is willing to delegate and live with the results.[12]

TechInvent, a firm that invents new products, is the setting of the fictitious case of this section. Mr Boss, TechInvent's manager, is responsible for deciding which invention the firm should pursue. Mr Maple, the researcher, tries to invent the suggested product. When an innovation succeeds, Boss takes care of the associated commercial activities, such as obtaining a patent and selling the patent to firms who want to produce the invention.

Maple is a researcher with a background in engineering. He is mainly motivated by private benefits. He is challenged by figuring out how to "make things work." His salary is fixed and does not therefore depend on the success of an invention.

TechInvent has to choose among three projects, called 1, 2, and 3. For a given level of effort exerted by Maple, project 1 is the most profitable, project 2 the second-best, and project 3 the least. However, the harder Maple works, the higher is the chance of success, and the higher are the expected profits. If he would work hard on project 2, and not very hard on project 1, then 2 would be more profitable than 1. Project 3 always yields less profits than project 1, regardless of the effort exerted by Maple.

By definition, Boss has formal authority. He may, however, wish to delegate responsibility to Maple, because Maple can be induced to

[11] See also *Managers Magazine* (1992) and McConalogue (1993).

[12] See also Horton (1992).

work harder by giving him influence (as we will see below). Therefore, although Boss has *formal* authority, it may be a good idea to give Maple some *real* authority. The question, how should Boss motivate Maple, is illustrated by the following quote:[13]

> "The issue [...] is where to draw the line around responsibilities and [...] freedom. I agree that it's important to delegate responsibility and empower people throughout the organization, but you also have to communicate clearly what the boundaries are around their jobs."

Boss can try to motivate his researcher by asking Maple to make a proposal for a project. Boss then only has to decide among which projects Maple is allowed to choose. He can tell Maple in advance which proposals will be accepted and which ones will be turned down. If a proposal is turned down, Maple has to work on project 1 (Boss's favorite project).

Based on experience, Boss and Maple know that there is a probability of roughly 33% that a project yields high private benefits to Maple. So on average there is one project that can trigger high effort by Maple. Initially, however, it is not known which project this is. By investing a certain amount of time and effort, Maple can find out the projects' private gains at once. For instance, even though the descriptions of the projects may be clear, Maple still has to figure out in which direction he wants to develop his skills and expertise. Only by figuring this out it becomes clear which project he prefers.

If Boss imposes a project, Maple may try to figure out his private benefits, but the odds are he will not like the project. Suppose that Maple finds it worthwile to figure out in advance what his gains are only if Boss gives him the freedom to choose among all three projects. This assumption will be crucial in the analysis.

[13]Norm Poole, Executive Vice President, Chief Operating Officer, and a Director of L.L. Bean of Freeport, a leading U.S. mail-order firm that sells equipment for outdoor activities (Continental Bank (1993), p. 50).

Accordingly, Maple proposes a project if he knows his personal gains. His proposal will then be his preferred project. Therefore, Boss learns Maple's preferences only after a proposal.

The provisional conclusion is that Boss faces a choice among:[14]

- Imposing project 1 (Boss's favorite project). Maple will not take initiative to get informed about his private benefits.

- Letting Maple choose among 1 and 2. Maple will not take initiative to get informed about his private benefits. He then has to implement project 1.

- Letting Maple choose among 1, 2, and 3. Maple is motivated to find out his personal gains and will make a proposal.

Notice that too little freedom for Maple (letting him choose among 1 and 2) is the same as no freedom (imposing 1). This is due to the assumption that Maple needs three projects to become interested to figure out what he wants to do.

Boss faces the following tradeoff. On the one hand, imposing project 1 does not trigger initiative. Maple has no incentive to learn his private benefits and make a proposal. Boss's favorite project will be implemented, but expectedly Maple will not work hard. Accordingly, authoritive management demotivates Maple, but keeps Boss in control. On the other hand, enough freedom in project choice results in initiative: Maple will learn his private benefits and recommend his preferred project. This may not be Boss's favorite project, but Maple will work hard. Thus, hands-off management, that is, empowering Maple, triggers interest and initiative but decreases Boss's real authority.

A problem may arise, however, if Boss gives Maple complete freedom but cannot stick to his promise. If Maple proposes 3, it is optimal for Boss to impose 1 instead (recall the assumption that 1 with low

[14] The possibilities of letting Maple choose among 2 and 3, or among 1 and 3, can safely be ignored because giving him a choice among 1 and 2 is at least as good for Boss.

effort is more profitable than 3 with high effort), although this would imply breaking his promise to Maple. One may ask: why wouldn't Boss then let Maple choose among only 1 and 2? He doesn't because he knows that Maple will get informed and recommend his preferred project only if he can choose among all the projects. Although giving Maple complete responsibility is risky because he might propose 3, it is the only way to motivate him to take initiative.

The situation in which one wishes to change an action after a certain event is called **time-inconsistency**. A perhaps easier way to explain this is the following. Suppose I ask you to participate in a gamble. I will toss a coin. If it comes up "heads," I give you 50 guilders, and if it comes up "tails," you pay me 5 guilders. Let's say that you participipate and the coin comes up tails. I guess you wish that you could turn back the clock and refuse to participate. The time-inconsistency is that you are willing to play, but if you do and you lose, you wish that you had refused.

Back to TechInvent. If Boss cannot credibly promise not to reject a proposal for 3, Maple will not find it worthwile to make a proposal in the first place. How can Boss commit himself to a promise? If Boss and Maple have to work together at TechInvent in the future, Boss has incentives to keep promises. By breaking promises easily, he would perhaps not only demotivate Maple, but he would also lose credibility – an event with a backlash that would seriously damage TechInvent's corporate culture. Another way to gain credibility for Boss is to change his own incentives by contracting with a third party, such as an outside investor. By paying an investor a larger payoff if 1 is realized than if 3 is realized, Boss (who now cares about profits minus the payoffs to the investor) can manipulate his own incentives such that he will not break his promise to Maple.

This example highlights two issues. First, it demonstrates an important tradeoff a manager may face when he delegates responsibility to a subordinate. Too little responsibility does not trigger initiative by the subordinate. Enough responsibility makes it attractive for the subordinate to figure out how he can realize private benefits, so that he will work hard. The manager, however, then loses influence. Second, depending on the manager's incentives, delegation of responsibility only works if the manager can be expected not to break his promise to his subordinate.

1.6 Strategic Delegation of Responsibility in Competing Firms

There are several real-world examples of managers at lower levels who have a say in their firm's strategy. For instance in the car industry:[15] "Honda developed its Civic car by giving a group of young middle managers broad guidelines (make it youth-friendly and fuel-efficient) and letting them get on with the job." The freedom of Honda's middle managers may not only have been an important motivator that triggered initiative, it should also be viewed as a decision about where to position the car. Another example is the following: "Motorola's middle managers have had a large say in designing its Iridium satellite project." Belasco (1992) presents a case study of a firm that proceeded with international expansion plans by maximizing employee empowerment. An important insight of his study is that empowerment is a powerful competitive weapon.

Without knowing the details of the Honda and Motorola cases, one can argue that considerations about motivating employees while at the same time formulating a market strategy may have played a role. These examples were presented in *The Economist* (1995) to illustrate the claim that firms which give middle managers a say in determining strategy perform better. To investigate linkages between organization and market strategy, I will apply the main idea of section 1.5 to a setting

[15]The next two quotes are taken from *The Economist* (1995), p. 70.

with competing firms.

The main players in this fictitious case are a product manager and a middle manager of Tattler, a beer brewery competing with a small number of other breweries. Price competition is intense. In order to enjoy higher profits, Tattler has an incentive to position its brand in a market niche.

Consumers have different preferences for different beer varieties (such as lager beer, beer without alcohol, "white" beer, and so on). For a given beer type, consumers are willing to pay more for higher quality.

Tattler has a simple internal organization (see figure 1). It consists of a product manager, mr Boss, and a middle manager, mr Gibbs, who represents the engineers. Boss has to decide which beer type Tattler will sell and at what price. Gibbs takes care of development and production. Product quality is determined by the effort exerted by Gibbs. For instance, Gibbs' effort to motivate the people of his department determines how hard they will work at developing a new beer type.

Boss can be considered as the market player; he competes with the rival breweries by deciding on price, quality, and product position. However, in order to produce high quality, Boss will have to motivate Gibbs to work hard.

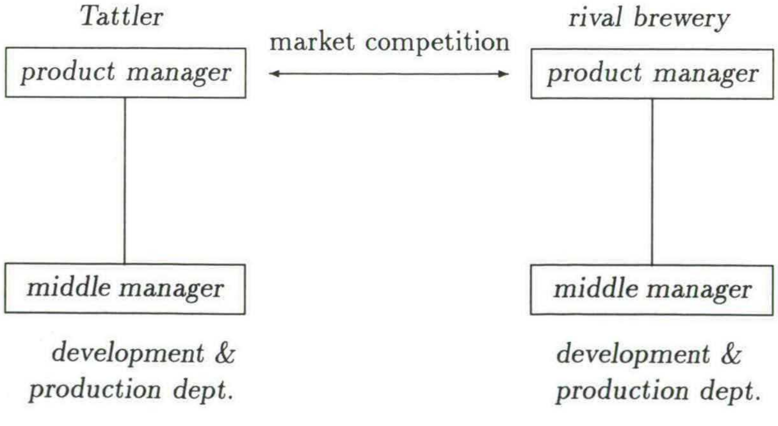

Figure 1: *Competition and internal organization*

Boss wants to maximize the firm's profits, whereas Gibbs cares about **private benefits**. For instance, because of career concerns he finds the acquisition of professional experience important. Alternatively, he is challenged by technical innovativeness of beer types (think e.g. of beer without alcohol). Since developing and producing different beer types requires different know-how (e.g. about inputs such as barley and hop, and about production processes such as filtration, lagering and brewing), these private benefits will typically vary over different beer types.

For expositional purposes, I assume that the possible brand locations vary from the market niche that Boss would like to aim at, to a location relatively close to the brands of the major competitors. This assumption will create a tension between Boss's wishes and Gibbs' preferences, which in turn will result in a tension between locating the brand in a niche and producing a premium brand.

Gibbs has to reflect on how to develop and produce beer types, and in which direction he wants to develop his own skills and expertise, before he can assess his personal gains. He has to invest time and effort to figure this out. Boss does not know Gibbs' preferences over the possible product varieties.

Boss can either impose which beer type the firm will sell (e.g. impose light beer), or give Gibbs a say in in the choice of a variety by letting him choose in a range of types. If this range is large enough, Gibbs will take initiative, that is, get informed about his private benefits and make a recommendation. If Boss adopts this proposal, Gibbs can gain large private benefits and will therefore work hard. By assumption, high quality will then result.

A crucial observation can be made by taking a closer look at Boss's tradeoff. Suppose that he delegates more responsibility. Gibbs gets more eager to make investigations about his personal gains and make a recommendation. Following up Gibbs' proposal will result in high quality beer (a premium brand). A drawback of empowering Gibbs is that

Boss loses influence. Indeed, it becomes more likely that Gibbs comes up with a proposal for a beer type that will not be very differentiated from rival brands. Intense price competition will then reduce profits.

Conversely, suppose that Boss delegates less responsibility. He is then better able to position Tattler's brand in the market niche, which is good for profits. However, it becomes less likely that Gibbs sees ways to realize private benefits; he becomes less enthusiastic to take initiative and work hard. It is then likely that Tattler's beer will be of low quality.

Summarizing, the optimal degree of freedom for Gibbs is determined by finding a balance between:

1. creating an organization that fosters initiative and quality,

2. positioning the brand in a market niche.

Which way the balance goes depends on different factors. The larger the impact of high quality on profits compared to the impact of product differentiation, the more freedom Gibbs will get. Also, the optimal level of discretion for Gibbs will be an optimal reaction to choices made in rival breweries. Boss will take into account what the other breweries in the market do, or, if he can imperfectly observe the actions of rival firms, he must form expectations of the behavior of his rivals.

Delegation of responsibility may serve various strategic purposes. For instance, it may help Tattler to become a *tough competitor.* If Boss gives Gibbs a large say in brand positioning, then high effort by Gibbs is more easily triggered so that a premium brand can be realized. At the same time it becomes more likely that there will be little product differentiation among the rival brands, so that price competition will be fierce.

Empowerment of Gibbs may also be a way to deter entry of potential rival firms. Consider a situation in which Tattler faces a potential entrant. Since delegation makes Tattler a tough competitor, an optimal *entry deterrence* strategy is empowerment of Gibbs. An optimal *entry* *accomodation* strategy (which may be optimal if deterring entry is too costly) should soften competition, and therefore entails little freedom for Gibbs.

As we have seen above, an authoritarian leadership style with regard to Gibbs (Gibbs has little responsibility) corresponds to a soft stance on the product market (i.e., with regard to rival firms). Similarly, "hands-off" management corresponds to an aggressive market stance. Therefore, leadership styles may be perceived quite differently inside and outside an organization. In the context of this example, statements like "Boss is a tough manager" have little meaning if one does not specify with regard to whom.

One should be aware that the results on strategic effects of empowerment and the perception of management style depend crucially on the set-up of this example. Applications of these results will not be justifiable in certain cases. Still, by understanding how diverging incentives inside an organization affect strategy, one can go through the arguments in different set-ups and see what comes out.

The main point of this example is to show that delegation of responsibility may affect a firm's strategy. The example demonstrates in detail how, under specific assumptions, a manager can make his firm compete more or less aggressively by giving his subordinate a smaller or larger say in the choice of positioning a product. Motivating employees and designing strategy are often viewed as separate activities for a manager. I want to stress that these activities may be intertwined.

1.7 Aftermarkets: The Monopoly Case

After-sales repair services and replacement parts are of major economic importance in many industries. Consider, for instance, the car industry, in which estimations of the market for parts and services vary between 114 and 125 billion USD per year:[16] "A typical dealership earns most

[16]See Emond (1993) and Taylor (1993).

money from servicing and parts; only 15% of its profits come from new car sales."[17] Perhaps this is due to the fact that prices of repair services and replacement parts often tend to be relatively high. For example, in the United States, constructing a car by buying all the necessary parts from retailers, ignoring assembly costs, costs three to eight times the price of a fully assembled car.[18]

There are some illustrations that in the information technology industry, firms experience inefficiencies due to high aftermarket prices: "The drive to reduce costs [...] has been taken up, too, by manufacturers, suppliers and specialist vendors keen to distance themselves from a possible user backlash."[19] Perhaps this can be explained by inefficient situations of high aftermarket prices. Also, some firms consider ways to get out of this undesirable situation. For instance, it was recently mentioned in the *Financial Times* that equipment sellers such as Compaq Computer and IBM try to design their systems to cut maintenance costs, whereas other firms contract out technical support.[20]

By abstracting from competition among manufacturers, and by giving a manufacturer the possibility to introduce competition in the repair market, this section provides a partial explanation for these casual observations.

The main player in the ficitious example is Read-It, a manufacturer of computers that perform a very specific operation: transforming handwritten text into a computer text file. It is the only supplier of these computers. Therefore, it can behave as a monopolist.

The production process at Read-It is imperfect. A small fraction of the computers breaks down after the use of a certain period. Read-It carries out the repair services; the cost to the firm of repairing is negligable. Because the service manuals of Read-It computers are copyrighted, the firm can make sure that no one else can repair its computers.

[17] *The Economist* (1994b), p. 72.

[18] See Voortman (1993).

[19] Taylor (1995), p. 1.

[20] Taylor (1995).

Repair services are sold *after* the purchase of the computer. Therefore, the market for repair services will be called an **aftermarket**. Aftermarkets arise if prices for repair services or replacement parts are not pinned down in a contract at the time of purchase of equipment. In this sense, the initial contract or transaction is called an **incomplete contract**.[21]

The game is simple. In a given period, Read-It sells computers and may also have to carry out repairs for customers who bought in the past. The question is what prices the firm should charge.

Since potential buyers of Read-It computers foresee that they may need repair services in the future, they do not base their purchase decisions only on the price of a computer, but also on the price they will have to pay for repairs. How can they know these prices? Of course, they can never know them for sure. However, customers can form beliefs based on Read-It's *current* prices, such as the repair price they observe at the time they buy a computer. A reasonable guess of the future repair price is the current repair price. Let's assume that the future repair price expected by customers is the repair price they observe at the time when they buy a computer. These "adaptive" beliefs are correct in situations in which market conditions are constant and Read-It does not have to adapt its prices. Therefore, we will consider prices that are once-and-for-all optimal.

If Read-It foresees how customers form beliefs, it can directly influence their beliefs by varying the repair price. For instance, by choosing a low repair price, the firm instantaneously establishes a reputation for being a low-cost repair service provider. This mechanism will be called the **reputation mechanism**.

Since Read-It is a monopolist, it can choose its prices as high as customers' willingness to pay for computers and repair services. Customers are willing to pay a higher price for a computer if they expect a lower

[21]Even when "complete" maintenance contracts are possible, they often prove to be worthless for consumers; see a report by the European Consumer Law Group (1988).

risk of breakdown or a lower repair price. Accordingly, Read-It can charge higher prices for computers if consumers expect less problems in the future.

In a given period, Read-It has to choose a computer price for new customers, and a repair price for clients who bought in the past. Because of the assumptions about customers' beliefs and the reputation mechanism, Read-It's tradeoff is fairly straightforward. Roughly, it can either sell computers at a high price and choose a low repair price, or sell at a low price and charge a high repair price. If both prices are high, new customers find price and future maintenance costs too high to be interested to buy.

Let us assume that customers are **risk-averse**, that is, they do not like to incur risk of breakdown (e.g. they are hit hard by computer breakdowns). Read-It has a deep financial pocket that can absorb shocks and is not risk-averse. These assumptions have the following consequence. Suppose Read-It decreases the repair price. Because of the reputation mechanism, consumers who observe this price expect lower repair prices in the future, so that their willingness to pay for computers becomes larger. For Read-It, this increase in customer' willingness to pay *more than offsets* the decrease in future returns from repairs.

Because customers are risk-averse, Read-It would want to promise that repairs will be carried out for free. The only way to commit to a low future repair price is to use the reputation mechanism. One would therefore expect that the repair price should be low. However, this would only be optimal when Read-It wouldn't have locked-in customers, that is, customers with Read-It computers. Since Read-It does have locked-in customers, some of the computers sold in the past will break down. The owners of these computers are "stuck" and can be "exploited" by charging a high repair price. The conclusion is that because Read-It has locked-in consumers, it will choose a relatively high repair price. The price of a computer can then be chosen as high as customers' willingness to pay given their expectations about future maintenance costs.

How high the optimal repair price should be depends, among others, on the quality of its computers. To see this, suppose that the quality of its computers gets worse. Then a larger fraction of its computers will break down. Consequently, more locked-in customers in need of repairs can be exploited. Since the value of a "low maintenance costs" reputation remains constant (as long as the size of the market remains the same), it becomes more tempting to exploit locked-in customers. For this reason a deterioration of the quality of Read-It's computers will result in a higher repair price.

It is interesting to consider what would happen if maintenance contracts would be possible (recall that these were assumed to be impossible). Consider contracts that specify, at the time of purchase of a computer, the future repair price. If a computer breaks down, its owner can have it repaired at the price stated in the contract. Since customers are risk-averse, the optimal contract specifies that repairs are carried out for free. Effectively, such a contract insures consumer against the risk of breakdown. This outcome is in contrast with the inefficient aftermarket situation, in which the repair price is high and customers bear risk. Therefore, if long-term contracts were possible, Read-It would use them to commit itself to low repair prices.

Thus, under the absence of maintenance contracts, Read-It's incentive to exploit locked-in clients results in an inefficiently high repair price. Can the firm do something about this? A possible way to commit itself to low repair prices is "second sourcing" in the repair market, that is, inviting a competitor. Competition to carry out repairs will drive down repair prices to a level close to the repair cost. As a result, the risk incurred by customers is reduced.

An alternative way to reduce the aftermarket inefficiency is to lease computers instead of selling them. It is not difficult to see why this works. If lease periods are short, customers can return defective computers to Read-It when a lease period expires, and get a new or repaired one in the next period. Since customers do hardly incur risk in this situation, their willingness to pay increases.

This example demonstrates that a monopolistic manufacturer of a good that can break down, charges an inefficiently high repair price to risk-averse consumers if maintenance contracts cannot be written. The inefficiency is due to the presence of locked-in consumers, which can be exploited by choosing a high repair price. Optimal maintenance contracts would "insure" buyers against the risk of breakdown by fixing the future repair price at zero. This would result in an increase of buyers' willingness to pay for the good. The manufacturer, however, has ways to improve upon the situation. Inviting a competitor (second sourcing) in the repair market is beneficial because it results in lower repair prices. An alternative solution is leasing the good instead of selling. In that case the firm instead of customers bears the risk of breakdown.

1.8 Concluding Remarks

The examples in sections 1.3-1.7 included assumptions on which the outcomes were based. It is important to be aware that, in general, the outcomes will change if one changes the assumptions. Moreover, the assumptions simplified the real world perhaps too much. As a consequence, one cannot directly apply the results to practical situations. Does this mean that the models and examples are irrelevant?

The answer is no. One should not literally interpret the models in this thesis. Instead, the insights are important (since they were summarized at the end of the preceding sections, I will not repeat them here). Understanding tradeoffs and mechanics of interaction may lead to a better understanding of real-world problems.

Saloner (1994) gives reasons why game-theoretic models can be powerful in general. First, they provide a detailed logic (an "audit trail") that can support claims about strategic behavior. For instance in the cases that were presented in this chapter, which are in fact verbal versions of the mathematical models, all the claims about optimal strategies can be supported by logical arguments. Second, models can generate novel insights, possibly unforeseen or surprising. Examples of results that I did not foresee initially include the limited strategic value of SuperCam's information about the quality of Digit's cameras (section 1.4), and the possibility that perceptions of a management style can diverge inside and outside an organization (section 1.6). Third, formal modeling provides a common language or unifying framework, allowing to compare related results and to understand empirical findings.

As noted above, if one changes the ingredients of a game-theoretic model (such as the number of players, the actions they can choose, or the timing of events), the outcomes may change as well. Some economists judge this sensitivity as a weakness of game theory. My view is that it only reflects reality; because of the complexity and vagaries of the real world, one cannot expect that models have broad applicability and give robust results. As Saloner (1994) argues, the enormous scope of the settings and decisions that managers must confront requires richly textured theory.

Game theory's potential promise for business practice is formulated by Camerer (1994, p. 198): "[...] I ask whether game theory provides sound advice for managers. It does not, but it answers questions managers should want to know the answers to, and it should be part of a sensible package of advice." Note that I wrote *potential* promise – I am optimistic, but we have to wait and see.

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Chapter 2

Moral Hazard and Noisy Information Disclosure

2.1 Introduction

The choice of an unobservable action by an agent may strongly be affected by the possibility to inform others about the actual choice of action. For instance, a seller who chooses the quality of the product he offers for sale, can decide whether or not to advertise product quality. In this chapter I investigate strategic disclosure of verifiable information in a noisy environment.[1]

In the model, messages that contain information about a hidden action of an agent called the sender, are costly to send. A message may not reach another agent, the receiver, because of noise. The noise is such that a message reaches the receiver with some probability smaller than one. Also, disclosed information is costlessly verifiable ex post, so that only thruthful messages are sent.[2] This assumption is justified

[1] Starting point of this chapter is work by Bester (1994), showing that when noise interferes with advertising, a monopolistic seller will necessarily choose a random advertising strategy.

[2] Grossman (1981) provides examples of sellers who can make verifiable disclosures about quality. In advertisements, a diamond seller can specify the weight of a diamond, and a fruit vendor can state how many oranges a box contains.

when, for example, the sender incurs legal liability if he lies (as in some countries in the case of misleading advertising). However, the sender does not *have* to inform the receiver; he can also remain silent. Finally, depending on whether or not he received a message, and if so, on its informational content, the receiver responds with an action.

The noise in the model exhibits properties of a mail system: a message may get completely lost, but if it is received, the information is not distorted. For instance, if a seller advertises in a newspaper, consumers might not receive it. Alternative interpretations of the noise are that a consumer may overlook an advertisement, or, that an agent (e.g. a manager) can only pay attention to a fraction of the information he receives, due to work overload.

I assume that the sender dislikes exerting effort, but wants the receiver to choose a "high action," for instance, to work as hard as possible. Due to complementarities, the receiver is willing to choose a high effort level if he knows or believes that the sender exerted high effort. The model encompasses several interpretations; applications are discussed formally.

Intuitively, the agents effectively play a simultaneous-move game if the amount of noise and disclosure cost are prohibitively high. In the more interesting case of sufficiently low noise and disclosure cost, there exists a unique equilibrium in which the sender randomizes between (i) exerting minimal effort and remaining silent, and (ii) exerting high effort and informing the receiver. This high effort level, however, is lower than the effort level that would be selected if there was no noise.

What is the intuition behind the sender's randomizing behavior? First, the sender will not exert minimum effort with certainty, because selecting and revealing a high effort level results (expectedly) in a more beneficial response by the receiver; commitment is advantegeous. Second, suppose that the sender selects and reveals some high effort level with probability one. Then, in equilibrium, the receiver plays his best response to the sender's action, also if he receives no message (which may occur because of the noise). But then the sender can deviate by exerting minimal effort and remaining silent, a contradiction.

If the noise disappears, the equilibrium outcome converges to the regular Stackelberg outcome. Consequently, the presence of a little amount of noise affects the benefit of commitment only to a small extent. This convergence result, which also holds if signals are exogenously sent, complements recent work by Bagwell (1995).[3] Bagwell argues that predictions from commitment models are valid only if there is perfect observation of the committed action. This claim is supported by a model in which two players move sequentially. The second-mover receives a signal that may consist of any element of the first-mover's set of actions, that is, the signal is randomly garbled according to a distribution with non-moving support. Then, with even a small probability that a signal is garbled, the outcome of the associated simultaneous-move game is obtained.[4] [5] When the noise is such that certain signals can only be generated after certain actions (as in my model: a high signal after a high action), then commitment can be obtained in equilibrium.[6] The reason is that then the sender has some ability to inform the receiver of his action.

Another result is that if the disclosure cost tends to zero, the sender's equilibrium strategy does not converge to a pure strategy. Hence, the noise – not the disclosure cost – gives the sender an incentive to keep the receiver in the dark.

Seminal work on disclosure of information is Grossman (1981), in which the product quality of a monopolist is determined by nature. The monopolist knows the quality and can disclose this information at zero cost to a potential buyer. The highest-quality type has an incentive to

[3]See also Chakravorti and Spiegel (1993) and Van Damme and Hurkens (1995).

[4]Bagwell restricts to pure strategies to obtain this observation; implicitly he needs an equilibrium selection criterion.

[5]In Bagwell (1995), signals are exogenously sent; this is not crucial for his result.

[6]This is also true if signals are sent exogenously. Then the sender will not randomize; see section 2.4.

disclose his private information since he does not want to be mistaken for a lower-quality type. Once the seller with the highest quality identifies himself by disclosing his type, the next-highest quality seller also wants to separate himself from the lower-quality types. Repeating this argument yields that the seller always announces his quality because buyers will assume the worst if they receive no information.

In Verrecchia (1983), disclosure is costly. A manager decides to reveal or withhold information about the liquidating value of a risky asset. Asset traders who receive no information are unsure about whether the withheld information represented bad news or the disclosure cost was prohibitively high. The result is that the manager will only disclose information that represents a value above some threshold level.[7]

Two features of my model constitute important diffences with the literature on information disclosure, and lead to quite different results. First, in my model the sender takes a hidden action. This feature allows one to address the interdependence of commitment and disclosure. The next difference is the presence of noise in my model, which has interesting implications on moral hazard and the ability to commit. Since the receiver does not know whether a message was sent or not when he does not receive one, there is a moral hazard problem that does not arise in the existing literature, although it may be important in several situations.

The model is a departure from signaling and cheap talk games, in which there is no noise. Furthermore, in signaling games, (see e.g. Spence (1973) and Cho and Kreps (1987)), signals provide no hard information except that they may allow some types to distinguish themselves. Due to the fact that different types have different preferences (or incur different costs) about signals, observable actions or outcomes (e.g. profits) can be used to infer the sender's type. In my model it is

[7]Also on disclosure, Jovanovic (1982) addresses the question of whether market incentives are sufficient to induce disclosure of the quality of a commodity. In particular, Jovanovic studies public policies concerning voluntary versus mandatory disclosure when quality is a random event.

crucial that "disclosure" is the provision of hard, truthful information.[8] In cheap talk games (see e.g. Crawford and Sobel (1982)), signals are costless, unverifiable and non-binding. Moreover, a standard assumption in the literature on signaling and cheap talk is that the sender is privately informed about his type, selected randomly by nature. In my model, private information concerns a hidden action.[9]

The model, some applications, and equilibrium notion are presented in section 2.2. Section 2.3 derives the equilibra. In section 2.4, comparative statics are derived and the results are discussed. Section 2.5 concludes.

2.2 The Disclosure Game

Consider a game with two agents: a sender, called S, and a receiver, called R. S chooses a hidden action $t \in T = [\underline{t}, \bar{t}\,] \subset \mathbf{R}$, together with a decision whether to send a message stating "*I have selected action t.*"[10] So S can choose to remain silent. The choice of action is described by a probability distribution function $F : T \to [0,1]$. The probability of sending a message when action t is chosen, is denoted by $r(t) \in [0,1]$. Let supp F denote the support of $F(\cdot)$.

Signals can be costlessly verified, so that S cannot lie. Revealing his action is costly for S: he has to pay a cost $c > 0$ when he informs R.[11] Nature may prevent R from receiving information, that is, inde-

[8]As Leland (1981) points out, a signaling game can incorporate a disclosure game. In a signaling game, truth-telling will occur in equilibrium if the cost of lying is prohibitively high, and disclosing no information can be viewed as sending a particular signal.

[9]De Groote (1990) analyzes cheap talk in a moral hazard setting. Austen-Smith (1994) investigates cheap talk when the sender has to incur a cost to observe the state of nature.

[10]One can show that if Nature chooses t according to a random distribution, then S informs R of his type if and only if t is above some critical level; see Verrecchia (1983).

[11]For instance, c represents the cost of an advertisement or the price of a

pendently of t, R receives a signal with probability $\lambda \in (0,1)$. The value of $1-\lambda$ will be called the level of noise. The values of c and λ are common knowledge. If R observes a signal, he chooses action $a(t) \in A = [\underline{a}, \overline{a}] \subset \mathbf{R}$. Otherwise, he selects some action $a_0 \in A$.

The payoff functions of S and R are $U_S(t,a)$ and $U_R(t,a)$, respectively. Each function is twice continuously differentiable in t and a.

Assumption 1 *$U_S(t,a)$ is (i) strictly increasing in a for all t; (ii) strictly decreasing in t for all a; and (iii) strictly concave in (t,a).*[12]

An interpretation of assumption 1 is that S dislikes exerting effort so that he wants to shirk, but he wants R to exert a maximum level of effort.

Assumption 2 *$U_R(t,a)$ (i) is strictly concave in a for all t; and (ii) satisfies $\partial^2 U_R(t,a)/(\partial t \partial a) > 0$.*

By assumption 2, for each action of S, R has a unique payoff-maximizing response. Moreover, the best response of an informed receiver will be increasing in the sender's action (see section 2.3).

Example 1: *Quality selection and advertising*
This example draws on Grossman's (1981) disclosure model. Consider a monopolist (S) who can choose the quality t of the product that he offers for sale. The price of the good is the same for all qualities (this rules out the possibility that the price is informative). A potential buyer (R) receives an advertisement only with probability λ. He purchases the good with probability $a(t)$ if he observes an advertisement, and with probability a_0 otherwise. S's profit function is decreasing in quality (high quality is costly to produce), and increasing in a. For instance, $U_S(t,a) = a(r - C(t)) + (1-a)(-C(t)) = ar - C(t)$, where $C(t)$ is the unit cost of producing quality t, $C'(t) > 0$, and r denotes

stamp. Alternatively, S dislikes taking the effort of informing R.

[12]All the results except uniqueness of the disclosure equilibrium (see proposition 1) also hold when $U_S(t,a)$ is concave in (t,a).

the price of the good. R's net benefits are increasing in quality. For instance, $U_R(t,a) = a(t-r)$.[13]

Example 2: *Government procurement and environmental policy*
Consider a firm (S) with a pollutive production process, and a government agency (R) that has to decide on a procurement contract with the firm. S selects an investment level t in equipment that reduces pollution. Subsequently, S can send evidence of these environment-friendly expenditures (a dossier that consists of brochures and bills) to R. Suppose that R, while choosing the expenditure level a, takes S's environmental effort into account. A possible reason is that the government wants to stimulate "green" behavior. Accordingly, $U_R(t,a)$ is increasing in t. Because of government bureaucracy, with positive probability S's dossier gets lost. Since S may not care about pollution, profits $U_S(t,a)$ are decreasing in t, the money spent on equipment for pollution reduction. S's profits are increasing in a.

Example 3: *Efforts in a cooperative*
Suppose that there are two workers in a cooperative, S and R. S chooses an effort level t, and R an effort level a. The efforts are inputs in a production process that is described by a production function $F(t,a)$. S's effort is preparatory; for instance, he has to fine-tune equipment. After observing t, R chooses an effort level $a(t)$, otherwise some a_0. When R remains uninformed about t, either S did not inform him or the message got lost. By assumption 2 (ii), the effort of R depends positively on the preparatory effort. The workers share the output $F(t,a)$ according to a given distribution $(\alpha, 1-\alpha)$. The payoff of a worker is his part of the output minus his effort, that is, $U_S(t,a) = \alpha F(t,a) - t$ and $U_R(t,a) = (1-\alpha)F(t,a) - a$. Assumption 2 (ii), equivalent to $\partial^2 F(t,a)/(\partial t \partial a) > 0$, reflects complementarity of the production pro-

[13] The fact that $U_R(t,a)$ is not strictly concave in a causes no problems, because it can be approximated by a strictly concave function such as $U_R(t,a) = a(t-r) + \sqrt{a}/n$ (n large).

cess.

The notion of perfect Bayesian equilibrium of Fudenberg and Tirole (1991) is used to solve the game. In an equilibrium:
(i) Given $a^*(t)$ and a_0^*, S optimally chooses $F(\cdot)$ and $r(t)$ for all t in the support of F.
(ii) If R does not receive a message, he has beliefs about which action S has chosen. These beliefs are determined by Bayes' rule.
(iii) If R does not receive a message, he optimally chooses a_0 given his beliefs. If he does receive a message t, he optimally chooses $a(t)$.

If S selects some t^*, that is, t^* is an element of the support of $F(\cdot)$, then for given $(a_0, a(t))$, t^* and $r^*(t^*)$ jointly maximize

$$\begin{aligned} r(t)[\lambda U_S(t,a(t)) + (1-\lambda)U_S(t,a_0) - c] + (1-r(t))U_S(t,a_0) = \\ r(t)[\lambda U_S(t,a(t)) - \lambda U_S(t,a_0) - c] + U_S(t,a_0). \end{aligned} \tag{1}$$

R's best-response function if he learns that S has chosen t is

$$a^*(t) = \arg\max_a U_R(t,a) \tag{2}$$

In an interior optimum for R we have that $\partial U_R(t, a^*(t))/\partial a = 0$. Differentiating this condition with respect to t, and using assumption 2, it follows that $a^*(t)$ is strictly increasing in t. By the Theorem of the Maximum, $a^*(t)$ is a continuous function.

According to Bayes' rule, R's beliefs if he does not receive a message are described by the probability distribution function

$$G(t) = \int_{\underline{t}}^{t} \frac{1 - r(t')\lambda}{\int_T (1 - r(\tau)\lambda)\mathrm{d}F(\tau)} \mathrm{d}F(t'). \tag{3}$$

R's best response if he remains uninformed is

$$a_0^* = \arg\max_a \int_T U_R(t,a)\mathrm{d}G(t). \tag{4}$$

2.3 Analysis

As a starting point I will briefly discuss two games that are closely related to the disclosure game. If $\lambda = 0$, the game is equivalent to the game in which S and R simultaneously choose actions (the *simultaneous-move game*). It is straightforward to show that this game has a unique Nash equilibrium, in which S chooses his dominant strategy $\underline{t}$ and R selects $a^*(\underline{t})$.

Next, suppose that in the disclosure game, $\lambda = 1$, that is, R can perfectly observe S's message (the *Stackelberg game*). The following assumption, which will hold throughout the chapter, assures that the Stackelberg game has an equilibrium in pure strategies that yields S a higher utility level than in the equilibrium of the simultaneous-move game.

Assumption 3 *There exists a* $t > \underline{t}$ *such that* $U_S(t, a^*(t)) - c > U_S(\underline{t}, a^*(\underline{t}))$.

In an equilibrium of the Stackelberg game, S selects an action (called the Stackelberg action or strategy – although it is not necessarily unique)

$$t^{St} \in \arg\max_{t} U_S(t, a^*(t)). \tag{5}$$

Now return to the disclosure game, in which $\lambda \in (0, 1)$. Define

$$\xi(\lambda) \equiv \max_{t}\{\lambda U_S(\tilde{t}, a^*(\tilde{t})) + (1-\lambda) U_S(\tilde{t}, a^*(\underline{t}))\} - U_S(\underline{t}, a^*(\underline{t})). \tag{6}$$

The value $\xi(\lambda)$ represents S's maximal gain from choosing an action and informing R, gross of the disclosure cost c, and given that R will select $a^*(\underline{t})$ if he receives no message (R "assumes the worst"). By the Envelope Theorem, $\xi(\lambda)$ is strictly increasing. Also, $\xi(0) = 0$, that is, if there is so much noise that messages never arrive then independent of the disclosure cost, S will not inform R. Moreover, $\xi(\lambda) > 0$ for all $\lambda \in (0, 1)$.

The first result focuses on "no disclosure" equilibrium outcomes, which coincide with the equilibrium outcome of the simultaneous-move game as defined above. If sending a message is sufficiently expensive, or if the probability that a message will reach R is sufficiently low, then S will select $\underline{t}$ without informing R. The intuition is straightforward: if information transmission is prohibited by a high cost and a high level of noise, then S keeps R uninformed and the agents act as if they have to make their decisions simultaneously.

Proposition 1 *Suppose that $\xi(\lambda) \leq c$. There exists a unique equilibrium. In this equilibrium, S chooses action $\underline{t}$ with probability 1 and sets $r^*(\underline{t}) = 0$, and R chooses action $a^*(\underline{t})$.*

Proof: Suppose that in equilibrium $r^*(t) = 0, \forall t \in \text{supp } F$. Since $U_R(t, a)$ is strictly concave in a, the receiver's expected payoff function is also strictly concave in a for all beliefs that he may hold. Therefore, a_0^* is unique and R does not randomize. This fact and assumption 1 (ii) ensure that S selects action $\underline{t}$ with probability 1 for all a_0^*. R rationally infers S's action choice in equilibrium, that is, his beliefs satisfy $G(\underline{t}) = 1$. Therefore, $a_0^* = a^*(\underline{t})$.

S does not disclose, that is, $r^*(t) = 0$ for all $t \in$ supp F, if and only if $U_S(\underline{t}, a_0^*) \geq \lambda U_S(t, a^*(t)) + (1 - \lambda) U_S(t, a_0^*) - c$ for all $t \in T$. Equivalently,

$$U_S(\underline{t}, a^*(\underline{t})) \geq \max_t \{\lambda U_S(t, a^*(t)) + (1 - \lambda) U_S(t, a^*(\underline{t}))\} - c. \tag{7}$$

Let $\lambda U_S(t, a^*(t)) + (1 - \lambda) U_S(t, a^*(\underline{t}))$ be maximized by $\tilde{t}$. By assumption 3, $\tilde{t} > \underline{t}$. Note that (7) is equivalent to $c \geq \xi(\lambda)$; see definition (6). □

In what follows, I assume that disclosure of information is not a priori precluded, that is, $c < \xi(\lambda)$. Note that since $\lambda \in (0, 1)$, this inequality holds if the disclosure cost is sufficiently small.

The following lemma shows, among others, that S's ability to commit is reduced compared to the Stackelberg game; he will never use a pure strategy in equilibrium.

Lemma 1 *Suppose that in equilibrium there is a $t \in$ supp F such that $t > \underline{t}$. Then (i) $r^*(t) = 1$, and (ii) $a^*(t) > a_0^*$. Moreover, S never chooses a $t > \underline{t}$ with probability* 1.

Proof: Let $t > \underline{t}$ be in the support of $F(\cdot)$.
(i) The expected utility of S from selecting t is $r^*(t)[\lambda U_S(t, a^*(t)) + (1-\lambda)U_S(t, a_0^*) - c] + (1 - r^*(t))U_S(t, a_0^*) \geq U_S(\underline{t}, a_0^*) > U_S(t, a_0^*)$. It follows that $r^*(t)[\lambda U_S(t, a^*(t)) - \lambda U_S(t, a_0^*) - c] > 0$, which implies

$$U_S(t, a^*(t)) - U_S(t, a_0^*) > c/\lambda. \tag{8}$$

By inspection of (1), it is optimal for S to set $r^*(t) = 1$.
(ii) Follows from $U_S(t, a^*(t)) - U_S(t, a_0^*) > 0$ and assumption 1 (ii).
Finally, if S selects some action $t > \underline{t}$ with probability 1 then in equilibrium R rationally infers S's action, whether or not he received a signal, so that $a_0^* = a^*(t)$. But then S can deviate by selecting action $\underline{t}$ and sending no message. To see this, notice that $U_S(\underline{t}, a_0^*) > U_S(t, a_0^*) > \lambda U_S(t, a^*(t)) + (1 - \lambda)U_S(t, a_0^*) - c$. (The second inequality follows from (8).) This yields a contradiction. □

Lemma 1 states that if S takes an action $t > \underline{t}$, then he will certainly inform R. Also, if R is informed that S selected some $t > \underline{t}$, he exerts more effort than if he remains uninformed. Finally, if S exerts more than the minimum level of effort, he will keep R guessing about the actual action that he takes by randomizing.

The next result clarifies what "cheating" means in the context of the disclosure game, namely that shirking implies remaining silent. The reason is that by selecting action $\underline{t}$, S cannot increase his expected benefits by informing R. This is due to the fact that an uninformed receiver takes an action that is at least as favorable to S as the optimal action of a receiver who is informed of $\underline{t}$. Moreover, sending a message is costly.[14]

[14]From the proof of the lemma it follows that if $c = 0$, then S is indifferent between revealing $\underline{t}$ and remaining silent, so that any $r^*(\underline{t}) \in [0, 1]$ is possible. However, all the results hold for $c = 0$ if one selects $r^*(\underline{t}) = 0$.

Lemma 2 *Suppose that in equilibrium* $\underline{t} \in supp\, F$. *Then (i)* $r^*(\underline{t}) = 0$, *and (ii)* $a^*(\underline{t}) \leq a_0^*$. *Moreover, S will not choose* $\underline{t}$ *with probability* 1.

Proof: Suppose that $\underline{t} \in$ supp F. Since $a^*(t)$ is strictly increasing in t we have that $a^*(\underline{t}) \leq a_0^*$ (claim (ii)). By assumption 1 (i), $U_S(\underline{t}, a^*(\underline{t})) - U_S(\underline{t}, a_0^*) \leq 0$, implying $\lambda(U_S(\underline{t}, a^*(\underline{t})) - U_S(\underline{t}, a_0^*)) - c < 0$. By inspection of (1), it follows that $r^*(\underline{t}) = 0$ (claim (i)). Finally, $c < \xi(\lambda$ implies that there exists a $t \in$ supp F such that $r^*(t) > 0$. By claim (i), $t > \underline{t}$, and therefore $F(\underline{t}) < 1$. □

The following result shows that in any outcome which is not a no-disclosure equilibrium, moral hazard prevails. Remember that assumption 3 assured that S optimally selects some action $t > \underline{t}$ in the Stackelberg game. In the disclosure game, however, S will try to "cheat" R (in the sense of exerting no effort and not informing R) with positive probability.

Proposition 2 *Suppose that* $c < \xi(\lambda)$. *In any equilibrium, S chooses action* $\underline{t}$ *with positive probability.*

Proof: Suppose $F(\underline{t}) = 0$. By assumption 2 (ii) we have that $a^*(t)$ is strictly increasing in t. Therefore, $a_0^* > a^*(\underline{t})$. Let $\hat{t}$ be defined by $a^*(\hat{t}) = a_0^*$. Such a $\hat{t}$ exists by continuity of $a^*(\cdot)$, and $a^*(\underline{t}) < a_0^* \leq a^*(\bar{t})$. Moreover, as $a_0^* > a^*(\underline{t})$, we have $\hat{t} > \underline{t}$. By lemma 1 (ii), the support of $F(\cdot)$ is contained in the interval $(\hat{t}, \bar{t}]$. Since a_0^* maximizes

$$\int_{\underline{t}}^{\bar{t}} U_R(t,a)\mathrm{d}G(t) = \int_{\hat{t}}^{\bar{t}} U_R(t,a)\mathrm{d}G(t),$$

it follows from assumption 2 (ii) that $a_0^* > a^*(\hat{t})$, a contradiction. □

To establish existence of "disclosure" equilibria, I will focus on equilibrium outcomes in which S randomizes between (i) selecting action $\underline{t}$ and remaining silent, and (ii) selecting some action $t^* > \underline{t}$ and informing R. In such an equilibrium, S tries to exploit R's uncertainty when he does not receive a message.

For convencience, I assume the following:[15]

Assumption 4 *$a^*(t)$ is a concave function over the range where $a^*(t) \in (\underline{a}, \overline{a})$.*

Consequently, S's expected utility given the choice of some action $t > \underline{t}$ and R's equilibrium strategy (as given by (1) for $r(t) = 1$) is concave in t.[16] Accordingly, we will be able to show existence of an equilibrium in a convenient way. Assumption 4 is implied by a variety of functions $U_R(t, a)$. Examples of a general form are $U_R(t, a) = f(g(a) - h(t))$, such as $U_R(t, a) = -(a - 2t)^2$; and $U_R(t, a) = f(t, a) + h(a)$, such as $U_R(t, a) = (1 - \alpha)F(t, a) - a$ in example 3 in the previous section.

Proposition 3 *Suppose that $c < \xi(\lambda)$. There exists a unique equilibrium. In this equilibrium,*
(i) S chooses $\underline{t}$ and $r^*(\underline{t}) = 0$ with probability $1 - p^* > 0$, and chooses $t^* > \underline{t}$ and $r^*(t^*) = 1$ with probability $p^* > 0$;
(ii) R chooses action $a^*(t)$ after learning S's action, otherwise he selects some $a_0^* < a^*(t^*)$.

Proof: 1. Let

$$t^*(a_0) \in \arg\max_{t \in T} \{\lambda U_S(t, a^*(t)) + (1 - \lambda) U_S(t, a_0) - c\}. \tag{9}$$

Because $U_S(\cdot, \cdot)$ is jointly concave in t and a (assumption 1), and $a^*(t)$ is a concave function, we have that $\lambda U_S(t, a^*(t)) + (1 - \lambda) U_S(t, a_0) - c$ is concave in t. This implies that the correspondence $t^*(\cdot)$ is convex-valued. By the Theorem of the Maximum, $t^*(\cdot)$ is upper-hemicontinuous.
2. Let

$$\begin{aligned} p^*(a_0, t) \in \ & \arg\max_{p \in [0,1]} \ \{p[\lambda U_S(t, a^*(t)) + (1 - \lambda) U_S(t, a_0) - c] + \\ & (1 - p) U_S(\underline{t}, a_0)\}. \end{aligned} \tag{10}$$

[15]This formulation is more convenient than stating an assumption on the primitives of the model. One can obtain assumption 4 as a result of restrictions on $U_R(t, a)$.

[16]This in turn implies that the set of optimal actions for S in equilibrium is concave-valued. Thus assumption 4 allows for a fixed-point argument to show existence of an equilibrium; see proposition 3.

Note that $p^*(\cdot,\cdot)$ is a convex-valued and upper-hemicontinuous correspondence.

3. Let

$$a_0^*(p,t) \in \arg\max_{a\in A} \left\{ \frac{p(1-\lambda)}{(1-p)+p(1-\lambda)} U_R(t,a) + \frac{1-p}{(1-p)+p(1-\lambda)} U_R(\underline{t},a) \right\}. \tag{11}$$

Note that $a_0^*(\cdot,\cdot)$ is a convex-valued and upper-hemicontinuous correspondence.

Define the correspondence $\varphi : A \times T \times [0,1] \to A \times T \times [0,1]$ by

$$\varphi(a_0,t,p) = a_0^*(p,t) \times t^*(a_0) \times p^*(a_0,t).$$

Note that φ is convex-valued upper-hemicontinuous, and $A \times T \times [0,1]$ is compact and convex. Therefore, by Kakutani's Fixed-Point Theorem, there exists a triple $(a_0^*, t^*, p^*) \in A \times T \times [0,1]$ such that $(a_0^*, t^*, p^*) \in \varphi(a_0^*, t^*, p^*)$. This fixed point of φ, and $a^*(t)$, constitute an equilibrium. Finally, uniqueness is shown. By lemma 1, $r^*(t) = 1$ for all $t \in \{t \mid t \in \text{supp } F,\ t > \underline{t}\}$. Furthermore, $r^*(\underline{t}) = 0$ by lemma 2. The function $h(t) \equiv \lambda U_S(t, a^*(t)) + (1-\lambda) U_S(t, a_0^*) - c$ is strictly concave in t if $U_S(t,a)$ is strictly concave in (t,a). Hence, $\{t \mid t \in \text{supp } F,\ t > \underline{t}\}$ has exactly one element. □

When $\xi(\lambda) > c$, the outcome of the disclosure game is an intermediate case of the outcomes of the simultaneous-move game ($\lambda = 0$) and the Stackelberg game ($\lambda = 1$), discussed at the opening of this section. The presence of noise (an intermediate value of λ), leads to randomizing by S, which can be interpreted as intermediate commitment (compared to choosing the Stackelberg action with probability 1). Moreover, if S commits himself, he chooses an intermediate action, that is, lower than the Stackelberg action, but higher that the equilibrium action of the simultaneous-move game.

2.4 More Results and Discussion

2.4.1 Further Results

The probability with which S exerts high effort in a disclosure equilibrium, p^*, may depend on c and λ. Accordingly let $p^*(c,\lambda)$ denote an equilibrium value of p^* given c and λ. Similarly, one can write $t^*(c,\lambda)$. For the sake of argument, suppose that t^{St} is unique.

Proposition 4 *Consider a sequence $\lambda_n \to 1$. Then any associated sequence $t^*(c,\lambda_n)$ converges to t^{St}, and any associated sequence $p^*(c,\lambda_n)$ converges to* 1.

Proof: By (9), t^* converges to t^{St} as λ tends to 1. Suppose there is a sequence $\lambda_n \to 1$, such that $p^*(c,\lambda_n) < \overline{p}$ for all n, where $\overline{p} < 1$. Then for any n, S randomizes (and is therefore indifferent) between selecting the lowest action without informing R, and selecting a high action while revealing his action choice to R. Consider a particular λ_n, for n large. By (11) and because $p^*(c,\lambda_n)$ is bounded away from 1, a_0^* tends to $a^*(\underline{t})$ as λ_n goes to 1. By assumption 3 and since $c < \xi(\lambda)$, for n large enough there is an action $\tilde{t}(\lambda_n) > \underline{t}$ such that choosing this action with probability 1 and informing R results in a higher payoff for S than selecting $\underline{t}$ and remaining silent. Since $p^*(c,\lambda)$ is bounded away from 1, R's posterior beliefs when he receives no message put a probability tending to 1 to the event that S selected $\underline{t}$, as λ_n goes to 1. But then S can do strictly better by selecting $\tilde{t}(\lambda_n)$ with probability 1 and setting $r^*(\tilde{t}(\lambda_n)) = 1$, a contradiction. □

Proposition 4 is intuitive if one recalls the Stackelberg game (see the previous section). As the noise level goes to zero, the equilibrium outcome of a disclosure equilibrium converges to the Stackelberg equilibrium outcome, that is, S's ability to commit to high effort becomes strengthened.

Proposition 5 *Let $\lambda \in (0,1)$ be given, and consider a sequence $c_n \to 0$. Then any associated sequence $p^*(c_n, \lambda)$ does not converge to 1.*

Proof: Suppose not, then there is a sequence $c_n \to 0$ such that some associated sequence $p^*(c_n, \lambda)$ converges to 1. For a given c_n, S selects some action $t^*(c_n, \lambda) > \underline{t}$ (defined by (9)) with probability $p^*(c_n, \lambda)$. Note that $t^*(c_n, \lambda)$ is bounded away from $\underline{t}$. To see this, suppose not. Then, since $c < \xi(\lambda)$, S can gain $\xi(\lambda) - c_n > 0$ from choosing some action $\tilde{t}$ (bounded away from $\underline{t}$; see the proof of proposition 1) and informing R. Since this gain remains strictly positive as $c_n \to 0$, we have a contradiction. As $p^*(c_n, \lambda)$ goes to 1, R's posterior beliefs after not receiving a message attach probability tending to 1 to action $t^*(c_n, \lambda)$. Therefore, a_0^* as a function of c_n tends to $a^*(t^*(c_n, \lambda))$. Since $U_S(t, a)$ is strictly decreasing in t, S can deviate by choosing $\underline{t}$ and remaining silent, a contradiction. □

The interpretation of proposition 5 is that even if the disclosure cost goes to zero, S will not choose and reveal some high action with probability 1. Because of the presence of noise, there is always an opportunity to "cheat" R by exerting no effort (with positive probability), and remaining silent. Therefore, the noise, and not the cost of informing R, creates the moral hazard problem.

Does S or R benefit from the noise? Suppose that $c < \xi(\lambda)$ (otherwise the noise clearly hurts both agents; see proposition 1).

Proposition 6 *The presence of noise negatively affects S's expected utility. It negatively affects R's expected utility if $U_R(t, a)$ is increasing in t for all a.*

Proof: Let S's and R's expected benefits in a disclosure equilibrium be denoted by U_S and U_R, respectively. Since S is indifferent between the two options of his mixed strategy, and $t^* < t^{St}$, it follows that $U_S = p^*[\lambda U_S(t^*, a^*(t^*)) + (1-\lambda)U_S(t^*, a_0^*) - c] + (1-p^*)U_S(\underline{t}, a_0^*) = \lambda U_S(t^*, a^*(t^*)) + (1-\lambda)U_S(t^*, a_0^*) - c < U_S(t^*, a^*(t^*)) - c < U_S(t^{St}, a^*(t^{St})) -$

c. Since $\underline{t} < t^* < t^{St}$, $U_R(t,a)$ is increasing in t implies $U_R(\underline{t}, a_0^*) < U_R(t^*, a_0^*) < U_R(t^*, a^*(t^*)) < U_R(t^{St}, a^*(t^*)) < U_R(t^{St}, a^*(t^{St}))$. It follows that $U_R = p^*[\lambda U_R(t^*, a^*(t^*)) + (1-\lambda) U_R(t^*, a_0^*)] + (1-p^*) U_R(\underline{t}, a_0^*) < U_R(t^{St}, a^*(t^{St}))$. □

The assumption that R's utility is increasing in t is satisfied when there are complementarities (as in the examples of section 2.2). By proposition 6, both S's and R's expected utility levels are negatively affected by the presence of noise. In example 1 for instance, the ability to commit to produce high quality benefits both the seller and the buyer. Without noise, the monopolist selects quality such that the gains from trade are maximal. In general, complementarities can be exploited more efficiently without noise.

2.4.2 Robustness

The result that S randomizes between on the one hand choosing high effort and informing R, and on the other hand shirking and remaining silent, is quite robust. It is not driven by the fact that messages either are delivered or completely lost. The following features are crucial for this result: (i) some signals can only be generated after choosing a sufficiently high action, and (ii) the signal R receives when S shirks (e.g., no message at all) can also be received when S chooses a high action. Put differently, S must have some ability to inform R of this commitment, and certain signals leave R in the dark about S's action. Since R will be uncertain after a low signal, S will shirk with positive probability and generate a confusing signal (in the model, S remains silent).[17]

[17] An example of a model with garbled communication that leads to randomizing by S is the following. If S does not send a message, R receives a signal which is not correlated to S's action, and if S does send a message, there is positive correlation. E.g., without sending a message the signal is uniformly distributed on $[0, \underline{t}\,]$ independently of S's true action, and with informing R of action t the signal

Since high signals can only be sent after high actions, the signal technology has a "moving" support. With a non-moving support, different results can be obtained. In Bagwell (1995, see also the introduction), when the sender takes an action, then the probability that the receiver observes a signal specifying that action is less than 1. With the complementary probability, the receiver observes a signal specifying any element in the sender's set of actions other than the chosen action. Thus, the receiver may receive as message *any* element in the first-mover's action space, and he cannot conclude from his observation that a particular action has *not* been chosen. In particular, there are no signals that can *only* be generated after choosing high actions. Thus, R's signal may always be a wrong signal. The intuition why commitment cannot occur is straightforward. Suppose that in equilibrium, S commits himself to a high action. Independent of the signal he gets, in equilibrium R should choose the best response to S's equilibrium action. But then S has an incentive to deviate, even if the amount of noise is very small.

If S could not choose whether to send or not send a message, but messages would be sent exogenously, then S would not randomize in his action choice. To see this, suppose that $r(t) \equiv 1$, $\forall t$. One can interpret $1-\lambda$ as the probability that there is leakage of the information about S's action.[18] Given R's best response, S selects a unique action $t^* = \arg\max_t\{\lambda U_S(t, a^*(t)) + (1-\lambda)U_S(t, a_0^*)\}$: there is a unique, pure strategy equilibrium. Moreover, $\underline{t} < t^* < t^{St}$, and the equilibrium outcome converges to the Stackelberg outcome if the noise disappears.

is uniformly distributed on $[0, t]$.

[18]On information leakage, see e.g. Kambe and Matsushima (1990) and Matsui (1989).

2.5 Conclusion

This chapter analyzed a sender-receiver game in which the sender can provide hard information about the action that he has chosen. If the cost of sending a message and the level of noise are sufficiently low, there is a unique equilibrium in which the sender randomizes between (i) making the lowest effort and remaining silent, and (ii) choosing a higher effort level and informing the receiver. The sender exploits the noise to cheat the receiver, who is unsure about the sender's action if he does not receive a message.

An important directions for further research on disclosure of information is to focus on legal rules. For instance, there exist laws that mandate disclosure of information in stock markets. In other cases, laws limit disclosure for reasons of privacy. A better understanding of how legal rules affect transmission of information and strategic interaction is not only important for economists, but may also offer those interested in law new ideas.[19] Another extension can be explored by assuming that the receiver has to invest in order to extract information. Accordingly, not the sender but the receiver pays the transmission cost. In this case it is the receiver who decides to inform himself or not.

[19] See Baird et al. (1994), ch. 3.

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Chapter 3

Entry Deterrence and Signaling in Markets for Search Goods

3.1 Introduction

Being the first firm to enter a market can be advantageous – for instance, when consumers are uncertain about product quality, as in markets for search goods or experience goods.[1] If only the pioneering brand's quality is known by consumers after subsequent entry, there is informational product differentiation: consumers know the incumbent's quality but are uncertain about the entrant's. In such a setting, this chapter explores how search costs and informational asymmetries influence the possibilities for entry in markets for search goods.

Consider a market for search goods in which consumers know the quality of the good sold by an incumbent but are uncertain about a potential entrant. The incumbent and the entrant simultaneously choose prices which are observed by consumers before they decide which firm

[1]Search goods can be inspected to allow a quality assessment before purchase, whereas the quality of experience goods is only learned after a purchase. The distinction between experience goods and search goods was made by Nelson (1970).

to visit. A consumer who visits the entrant's store and finds out that product quality is too low given the price that is charged may switch to the incumbent before buying provided that the cost of searching is not too high. Expectedly, if search costs are high then the risk of lock-in, that is, of buying a low-quality good at a high price because visiting the incumbent is too costly, may discourage consumers from visiting the entrant.

There is a variety of examples of products that have quality as a search-characteristic. Fruit vendors often allow consumers to inspect the fruit before buying. Stores selling audio equipment provide demonstrations for clients to help them decide. Automobile sellers allow consumers to perform test drives so that an assessment of quality can be made. Search costs arise, for instance, when visiting another seller takes considerable time.

The chapter focuses on two questions. The first question – how do search costs affect the possibilities for entry – is posed in two different informational environments. To begin, I consider the case in which the incumbent does not know the entrant's quality (setting I). This somewhat "standard" set-up is natural in several cases. For instance, in a fruit market the incumbent may not know who is the supplier of an entrant, so that the incumbent does not have any inside information.

The incumbent may, however, have information that consumers do not have. Consider, for instance, markets for technically complicated products, where firms have more expertise. Alternatively, consider professionals who have knowledge about each other due to a common history such as a shared education. In the model, one can model such events by assuming that the incumbent observes the entrant's quality (setting II). This situation gives rise to signaling with common information: the prices of both firms, rather than only the entrant's price (as in setting I), serve as signals of the entrant's type to consumers.

By examining settings I and II, one can answer a second question: is the incumbent better off if it knows the entrant's quality? A related question is: would an informed incumbent act differently, that is, will this information be used? If this is the case, industry structure might be affected. An analysis of this issue may lead to clues about inter-industry differences when industries differ by their informational environments.

Setting I, the uninformed-incumbent case, leads to several insights. One result is that the entrant can signal high quality by choosing a sufficiently high price. The intuition is that if the entrant's price is so high that a consumer who would find quality to be low would switch to the incumbent, then this price will be a credible signal of high quality.[2] Under low search costs, consumers can visit the incumbent if the entrant's quality turns out to be lower than expected. Therefore, for a separating equilibrium, it makes no sense for a low-quality seller to mimic a high type, and a firm of higher quality than the incumbent can profitably enter. Moreover, for a separating equilibrium, if search costs are sufficiently high then fear of lock-in induces consumers to avoid the entrant; there is an entry barrier.

The search cost spans the separating equilibrium outcomes in an interesting way.[3] For low search costs, the equilibrium outcome of a complete-information model of Bertrand competition is obtained; the high-quality entrant captures the market. For high search costs, Bagwell's (1990) entry deterrence result in markets for experience goods is obtained (Bagwell's paper is discussed below and in section 3.3). Thus, if search is sufficiently costly, then a search good has the characteristics of an experience good.

Pooling equilibria exist only if search costs are sufficiently high. In a pooling equilibrium the entrant charges an intermediate price (in accordance with consumers' prior beliefs). Therefore, since a high price signals high quality, if search costs are low then a high-quality entrant could deviate by increasing its price.

[2]This is true even though demand is price-inelastic. Bagwell and Riordan (1991) show that high prices may signal quality if demand is elastic and high quality is more costly to produce.

[3]I am grateful to a referee of the *I.J.I.O.* for pointing out this issue.

Setting II, the informed-incumbent case, generates additional insights. If the incumbent's price is informative about the entrant's type, then the entrant can rely on its rival's price to inform consumers, so that it has a large degree of freedom in its price choice. In the light of this observation, one can argue that the notion of perfect Bayesian equilibrium (and also sequential equilibrium) allows for unreasonable equilibria. In order to rule these out, I apply (a customized version of) Bagwell and Ramey's (1991) refinement of "unprejudiced" sequential equilibrium. The criterion captures the idea that if a firm chooses an out-of-equilibrium signal, while its rival's equilibrium signal is informative, consumers will rely on the equilibrium signal.

If the incumbent's price is uninformative about the entrant's quality, then, by and large, the same results as in setting I are obtained. Intuitively, if consumers cannot infer the entrant's quality from the incumbent's price, it does not matter whether the incumbent actually knows the entrant's type.[4] Now suppose that the incumbent's price does depend on the entrant's type. The entrant, knowing that the incumbent can observe its type and that consumers realize this, has less difficulty in convincing consumers of high quality. As a consequence, entry is facilitated. This reasoning does not depend on the level of search costs; an informative incumbent's price helps the entrant to *circumvent* lock-in effects and incentive-compatibility problems.

A comparison of settings I and II leads to the following result. The incumbent is not able to exploit private information about the entrant in a profitable way, that is, it cannot improve upon its situation if it observes the entrant's quality. The reason is that *using* information about the entrant helps the entrant to overcome its informational disadvantage. Thus, the results suggest that the distribution of information between the incumbent and the entrant is unlikely to affect industry structure.

[4]However, a difference with setting I is that there exist pooling equilibria for a wider range of parameter values, due to the relaxed restrictions on out-of-equilibrium beliefs.

There is a closely related literature on entry and quality uncertainty. Areeda and Turner (1975), Williamson (1977), and Demsetz (1982) argued that in markets for experience goods, promotional pricing (perhaps below marginal cost) by an entrant may be necessary to induce consumers to try its product. Accordingly, the entrant incurs "information costs," that may be recouped when consumers purchase at a higher price after having experienced the product. Schmalensee (1982), Farrell (1986), and Bagwell (1990) formally examined the difficulty faced by a potential entrant to persuade consumers that it sells a high-quality product. The informational asymmetry may result in an entry barrier, even if the entrant's expected quality is higher than the incumbent's quality. My paper differs in two important ways. First, whereas the literature cited above considers experience goods, I examine markets for search goods.[5] As explained above, search costs crucially influence the signaling possibilities. The second difference is that I also study the case in which the entrant's type is common information.

The few papers on games with common information (that I am aware of) consider quite different issues. Matthews and Fertig (1990) study wasteful advertising by an incumbent and an entrant, both informed about the latter's quality, in a market for experience goods.[6] Entry occurs automatically, and the firms play a duopoly game in which beliefs affect demand levels. The entrant may have difficulty trying to influence beliefs because the incumbent (the second-mover) can counteract. Bagwell and Ramey (1991) investigate limit pricing by two incumbents, both informed about an industry cost parameter. Milgrom and Roberts (1986b) study competition among interested parties with common information, who try to persuade a decisionmaker to make a particular decision. These parties can only report truthful informa-

[5]Notice the difference with Klemperer (1987) who explores entry deterrence in the presence of switching costs. In his model, a consumer who previously bought from the incumbent incurs a cost if he decides to purchase from the entrant.

[6]The literature in which firms signal quality by wasteful advertising is based on ideas in Nelson (1970); see Milgrom and Roberts (1986a).

tion. The main result is that competition leads to the full-information outcome.

The model of setting I is presented in section 3.2 and analyzed in section 3.3. Section 3.4 adapts the model to deal with setting II. Section 3.5 concludes.

3.2 The Model of Setting I

Consider a market with an incumbent (firm 1) and a potential entrant (firm 2). Entry is costless. Quality levels are expressed as (monetary) utility reservation values. The incumbent's quality is known to be low and is denoted by $q_1 = q_\ell$. The entrant's quality is denoted by $q_2 \in \{q_\ell, q_h\}$, where $q_h > q_\ell > 0$. The entrant's quality is determined by Nature, which selects quality q_h with probability $\alpha \in (0,1)$.[7]

The number of consumers is normalized to 1 with each consumer buying at most one unit. A product of quality q, sold at price p, yields utility $q-p$. The reservation utility level is 0. The unit cost of producing low quality is $c_\ell \geq 0$, whereas producing high quality costs $c_h \geq c_\ell$ per unit. Higher quality generates a higher surplus:

$$q_h - c_h > q_\ell - c_\ell > 0. \tag{1}$$

Since the central task before the entrant is to persuade consumers to visit its store, I will say that entry occurs if the entrant captures a positive share of the market. Conversely, entry is deterred if the incumbent can prevent the entrant from making sales. This terminology makes sense because the cost of entry is zero, so that strictly speaking, entry may always occur (see also Bagwell (1990)). In particular, for

[7] Accordingly, since entry is costless and firm 2's quality is never less than firm 1's quality, the entrant faces only an informational disadvantage vis-à-vis the incumbent (cf. Bagwell's (1990) "pro-entry" assumptions). A possible motivation for the assumption that the entrant's product is at least as good as the incumbent's is that the technology used by the incumbent is readily available. However, with probability α, the entrant realizes a successful innovation which results in high quality.

separating equilibria I will focus on entry by the high-quality firm and for pooling equilibria on entry by both types.

Qualities and costs are fixed during the game. The firms compete by simultaneously setting prices p_1 and p_2 which cannot be changed. Only the entrant observes its type. The expected profits of firm i are denoted by Π_i. Social welfare, denoted by W, is defined as the sum of producers' surplus and consumers' surplus.

Initially, a consumer receives information (p_1, p_2). In order to find out q_2, he has to visit the entrant's outlet. Consumers' beliefs after having observed prices are denoted by $\mu(p_1, p_2)$, which is the probability attached to the event that the entrant sells a high quality product.

At a visit to the entrant's outlet, a consumer observes q_2. At a store, a consumer may decide not to buy, and if that happens, he may decide to visit the other firm. In the latter case, he incurs a search cost: future benefits are discounted by a factor $\delta \in [0, 1]$.[8]

The sequence of events is as follows. First, Nature selects the quality of the potential entrant and this is observed by the potential entrant. Second, the two firms simultaneously set prices, which are observed by the consumers. Third, consumers (who know the quality of the incumbent, but are uncertain about the entrant's quality) decide which firm to visit. Before purchasing, they may switch to the other firm.

The notion of perfect Bayesian equilibrium of Fudenberg and Tirole (1991) is used to solve for pure strategy equilibia. Firm 2's strategy is a function $p_2(q_2)$. Equilibrium prices are denoted by p_1^* and $p_2^*(\cdot)$.[9] A consumer's strategy will be informally described by his visiting and

[8]This way of modeling search costs is derived from Bester (1993). A higher value of δ corresponds to lower search costs.

[9]Since setting price below marginal cost is a dominated strategy, I will assume that consumers interpret a price below the unit cost of producing high quality as a signal of low quality. Also, a firm that produces low quality has no incentive to charge a price higher than the consumers' reservation value for low quality. The range of p_1, and the range of $p_2(q_\ell)$ will be restricted to $[c_\ell, q_\ell]$, and the range of $p_2(q_h)$ to $[c_h, q_h]$. Note that in a model of repeated purchases, these restrictions would rule out dynamic price strategies such as introductory offers.

purchasing behavior. A perfect Bayesian equilibrium consists of firms' price strategies p_1^* and $p_2^*(q_2)$, $q_2 \in \{q_\ell, q_h\}$, consumers' strategy as to which firm to initially visit, and once at a firm whether to purchase, not purchase, or visit the other seller, conditional on p_1, p_2, and consumer beliefs $\mu(p_1, p_2)$, such that

(i) each firm's price strategy maximizes its profits given its rival's strategy and consumers' behavior,

(ii) consumers' decisions maximize expected net benefits given their beliefs, and

(iii) consumers' beliefs on the equilibrium path are consistent with Bayes' rule and the firms' price strategies.

Since the incumbent cannot observe the type of a potential entrant, its price cannot convey information about the entrant's quality to consumers. Accordingly, if one considers deviations by the incumbent, consumer beliefs will not vary with the incumbent's price:[10]

Assumption 1 *Given an equilibrium price $p_2^*(q_2)$, consumers' beliefs satisfy $\mu(p_1, p_2^*(q_2)) = \mu(p_1', p_2^*(q_2))$ for all $p_1 \neq p_1'$.*

3.3 Analysis of Setting I

3.3.1 General Remarks

In the first-best outcome (the incumbent and consumers observe the entrant's type), a high-quality entrant attracts consumers. This outcome is attained for $\delta = 1$ (a situation implying consumers acquire complete

[10]The incumbent and consumers have exactly the same information, so that in order to rule out implausible outcomes, one must require that the incumbent's price p_1 cannot influence consumers' beliefs. This is the "no-signaling-what-you-don't-know" condition of perfect Bayesian equilibrium: a player's deviation should not signal information that he himself does not have (see Fudenberg and Tirole (1991)). This condition is implied by the consistency requirement of the sequential equilibrium concept of Kreps and Wilson (1982).

information before purchasing). Equilibrium prices in this outcome are p_1^*, $p_2^*(q_\ell) = c_\ell$, and $p_2^*(q_h) = c_\ell + q_h - q_\ell$. Expected profits are $\Pi_1^* = 0$ and $\Pi_2^* = \alpha(c_\ell + q_h - q_\ell - c_h)$. The first-best welfare level W^{FB} equals

$$W^{FB} = \alpha(q_h - c_h) + (1-\alpha)(q_\ell - c_\ell).$$

To start the analysis, it is convenient to introduce a parameter restriction and an assumption on consumers' beliefs. Suppose that $q_h - q_\ell > q_\ell - c_\ell$. Let $p_1^* \geq c_\ell$ be given. The best response of a high-quality entrant is a price $p_2^* = p_1^* + q_h - q_\ell$. Since $p_2^* \geq c_\ell + q_h - q_\ell > q_\ell$, price p_2^* signals high quality. Consumers are indifferent between the two firms. However, they visit the entrant; otherwise he could slightly decrease p_2^* (one can view the entrant's best response p_2^* as "just below" $p_1^* + q_h - q_\ell$). Search costs or informational asymmetries do not play a role under this parameter constellation: the price of a high-quality entrant is always larger than the reservation value for low quality. To focus on more interesting cases, I will assume that

$$q_h - q_\ell \leq q_\ell - c_\ell. \tag{2}$$

Next, notice that the entrant knows that consumers can get utility level $q_\ell - p_1^*$ by purchasing from firm 1. Moreover, he knows that a consumer who finds out that he sells low quality will switch to the incumbent if prices are such that

$$q_\ell - p_2 < \delta(q_\ell - p_1^*). \tag{3}$$

Accordingly, any price $p_2 > q_\ell - \delta(q_\ell - p_1^*)$ is dominated for a low-quality entrant, while this is not necessarily the case for a high-quality firm. Therefore, given equilibrium price p_1^* (rationally expected by consumers and firm 2 in equilibrium), a price p_2 that satisfies (3) should convince consumers that firm 2 sells high quality. Formally, I will use the following assumption:[11]

[11] Assumption 2 is an equilibrium refinement strongly inclining to the Dominance Criterion of Cho and Kreps (1987) and the "independence of never a weak best response" (INWBR) criterion of Kohlberg and Mertens (1986). See also Bester (1993), section III, for a similar beliefs restriction.

Assumption 2 *Given an equilibrium price p_1^*, consumers' beliefs satisfy $\mu(p_1^*, p_2) = 1$ for all p_2 such that $q_\ell - p_2 < \delta(q_\ell - p_1^*)$.*

3.3.2 Separating Equilibria

In a separating equilibrium, the entrant's price is informative and hence $\mu(p_1^*, p_2^*(q_\ell)) = 0$ and $\mu(p_1^*, p_2^*(q_h)) = 1$. Let δ_1 be defined by

$$\delta_1 \equiv 1 - \frac{q_h - q_\ell}{q_\ell - c_\ell}. \tag{4}$$

Note that $0 \leq \delta_1 < 1$.

Proposition 1 *Under assumptions 1 and 2, for any δ, there exists a unique separating equilibrium:*
(i) If $\delta > \delta_1$ then a high-quality firm enters; $p_1^* = p_2^*(q_\ell) = c_\ell$ and $p_2^*(q_h) = c_\ell + q_h - q_\ell$; $\Pi_1^* = 0$ and $\Pi_2^* = \alpha(c_\ell + q_h - q_\ell - c_h)$; the first-best welfare level $W = W^{FB}$ is attained.
(ii) If $\delta \leq \delta_1$ then the incumbent deters entry of a high quality firm; $p_1^* = p_2^*(q_\ell) = c_\ell$ and $p_2^*(q_h) = c_\ell + q_h - q_\ell$; $\Pi_1^* = \Pi_2^* = 0$; since $W = q_\ell - c_\ell$, an inefficiency exists.

Proof: In any separating equilibrium, $p_1^* = p_2^*(q_\ell) = c_\ell$ (a price $p_1^* > c_\ell$ will be undercut by the low-quality entrant with a price p_2 just below p_1^*, which in turn gives firm 1 an incentive to deviate).
Suppose that in a separating equilibrium a high-quality seller attracts consumers. Two conditions must hold. First, the entrant offers a better deal than the incumbent:

$$q_h - p_2^*(q_h) \geq q_\ell - p_1^*. \tag{5}$$

Second, if a consumer finds out that the entrant sells low quality, he does not buy but visits the incumbent (the entrant's incentive-compatibility constraint):

$$q_\ell - p_2^*(q_h) < \delta(q_\ell - p_1^*). \tag{6}$$

From (5) and (6) it follows that $\delta > \delta_1$.

Suppose that $\delta > \delta_1$. Can an outcome in which a high-quality firm enters be supported as an equilibrium? Consider prices $p_1^* = c_\ell$ and $p_2^*(q_h) = c_\ell + q_h - q_\ell$, and beliefs $\mu(p_1^*, p_2) = 0$ if $p_2 \leq q_\ell - \delta(q_\ell - p_1^*)$, and $\mu(p_1^*, p_2) = 1$ otherwise. These beliefs satisfy assumptions 1 and 2. Suppose that consumers visit the entrant if they observe prices p_1^* and $p_2^*(q_h)$. These strategies and beliefs constitute an equilibrium. By assumption 2 it cannot be that $p_2^*(q_h) < c_\ell + q_h - q_\ell$ (otherwise a low type could mimic a high type).

Suppose that $\delta \leq \delta_1$. If an equilibrium exists, then the incumbent deters entry of a high-quality firm. Consequently, $q_\ell - p_1^* \geq q_h - p_2^*(q_h)$, so that $p_2^*(q_h) \geq c_\ell + q_h - q_\ell$. Since firm 1 should have no incentive to increase its price, $p_2^*(q_h) = c_\ell + q_h - q_\ell$. The same beliefs as in the case $\delta > \delta_1$ support this outcome as an equilibrium. □

The main insight of proposition 1 is that a high-quality seller attracts consumers if and only if search costs are sufficiently low.[12] Intuitively, if search costs are low enough, the entrant knows that consumers who find out that it sells low quality will switch to the incumbent, so that a low-quality type has no incentive to mimic a high-quality seller. In this case, consumers' surplus is maximal, and the first-best welfare level is attained. The range of δ in which the first-best outcome can be supported as an equilibrium outcome, increases as the difference between high and low quality increases.

If the lock-in effect is severe, the risk of lock-in discourages consumers from visiting the entrant, so that there is an entry barrier, leading to an inefficient situation. Consumer are indifferent between the incumbent and the high-quality entrant. In equilibrium however, they must visit the incumbent, since otherwise a low-quality seller could profitably mimic a high-quality firm because of consumer lock-in.

[12] In proposition 1, market shares of the incumbent and low-quality entrant are not determined. Uniqueness is obtained, e.g., by assuming an equal split of the market.

3.3.3 Pooling Equilibria

In a pooling equilibrium, $p_2^* \equiv p_2^*(q_\ell) = p_2^*(q_h)$. By Bayes' rule, consumers' beliefs satisfy $\mu(p_1^*, p_2^*) = \alpha$. Since, independently of firm 1's price, a price $p_2 < c_h$ signals low quality and a price $p_2 > q_\ell$ signals high quality, it must be that $c_h \leq p_2^* \leq q_l$. Necessarily, $c_h \leq q_\ell$ must hold.

If the entrant captures the market, then the incumbent does not make any profits. If firm 1 serves the market then it charges a price $p_1^* = c_\ell$; otherwise a low-quality entrant could undercut p_1^* and attract consumers. Consequently, firm 1 earns zero profits in any pooling equilibrium outcome.

By assumption 2, any price p_2 that satisfies $q_\ell - p_2 \leq \delta(q_\ell - p_1^*)$ signals high quality. Therefore, in any pooling equilibrium

$$p_2^* < q_\ell - \delta(q_\ell - p_1^*). \tag{7}$$

An implication is that if the entrant's price is uninformative, consumers who find out that it sells low quality will not switch to the incumbent. Thus if the entrant attracts consumers, they take into account that they may end up buying a low-quality product at a fairly high price. Moreover, the notion of "entry" in the proposition below refers to the event that both types of entrant capture the market.

Proposition 2 *Under assumptions 1 and 2, pooling equilibria (with and without entry) exist if and only if $\delta \leq \delta_1$ and $\alpha \geq (c_h - c_\ell)/(q_h - q_\ell)$: (i) If entry occurs then $p_1^* \in [c_\ell, q_\ell - (q_h - q_\ell)/(1-\delta)]$ and $p_2^* \in [c_h, c_\ell + \alpha(q_h - q_\ell)]$ such that $q_\ell - p_1^* \leq \alpha q_h + (1-\alpha)q_\ell - p_2^*$; $\Pi_1^* = 0$ and $\Pi_2^* = p_2^* - \alpha c_h - (1-\alpha)c_\ell$; the first-best welfare level W^{FB} is attained. (ii) If entry is deterred then $p_1^* = c_\ell$ and $p_2^* = c_\ell + \alpha(q_h - q_\ell)$; $\Pi_1^* = \Pi_2^* = 0$; since $W = q_\ell - c_\ell$, an inefficiency exists.*

Proof: See the appendix.

3.3.4 Search Goods Versus Experience Goods

There is an important difference with Bagwell (1990), who investigates an experience good market in which consumers know that the incumbent sells low quality, and consumers and the incumbent are uncertain about the entrant. In a dynamic model, a reputation for high quality can be established by the entrant in the first of two periods. To signal its quality, a high-quality firm should select a price in the first period so low that it results in negative profits (in that period) only for the high-quality type. Thus, low prices can signal high quality. There is an entry barrier if the initial sacrifice of such a low price is prohibitively high; a low price is a costly signal. My model demonstrates that in markets for search goods, a sufficiently high price signals high quality.

An interesting link with Bagwell (1990) is the following. On the one hand, if search costs are sufficiently low ($\delta > \delta_1$; see proposition 1), then the equilibrium outcome (in terms of equilibrium prices and consumers' behavior) is identical to the equilibrium outcome of the Bertrand model with complete information. On the other hand, for high search costs ($\delta \leq \delta_1$; see proposition 1), if one considers separating equilibria, the equilibrium outcome of a static experience-goods model is obtained (see Bagwell (1990), Prop. 1, p. 212). In this sense, a search good may have the characteristics of an experience good.

3.4 Model and Analysis of Setting II

3.4.1 General Remarks

This section investigates the case in which the incumbent can observe the entrant's quality, while consumers are still uncertain. Since the incumbent's price strategy can depend on the entrant's quality, it is denoted by $p_1(q_2)$. The definition of an equilibrium given in section 3.2 has to be adapted to this change. It is common knowledge that the entrant and consumers know that the incumbent is informed.[13]

Assumption 1, no longer justifiable, is dropped. If the incumbent's price strategy satisfies $p_1^*(q_\ell) = p_1^*(q_h)$, then the intuition and motivation behind assumption 2 still holds. A slightly modified version of this assumption will be applied:

Assumption 3 *Given equilibrium prices* $p_1^* \equiv p_1^*(q_\ell) = p_1^*(q_h)$*, consumers' beliefs satisfy* $\mu(p_1^*, p_2) = 1$ *for all* p_2 *such that* $q_\ell - p_2 < \delta(q_\ell - p_1^*)$.

3.4.2 Separating Equilibria

In a separating equilibrium, at least one of the firms' prices is informative about firm 2's type, that is, $p_i^*(q_\ell) \neq p_i^*(q_h)$ for at least one i. Equilibrium beliefs are $\mu(p_1^*(q_\ell), p_2^*(q_\ell)) = 0$ and $\mu(p_1^*(q_h), p_2^*(q_h)) = 1$.

The fact that two firms try to signal common information may lead to unreasonable equilibria. The following example demonstrates this.

Example: *Free riding on the incumbent's signal*
Consider prices $p_i^*(q_\ell) \neq p_i^*(q_h)$, $i = 1, 2$ (see figure 1). Let $p_1^*(q_\ell) = p_2^*(q_\ell) = c_\ell$. Suppose that $q_\ell - p_1^*(q_h) = q_h - p_2^*(q_h)$ and consumers visit the incumbent after observing price combination $(p_1^*(q_h), p_2^*(q_h))$. Let consumer beliefs be such that firm 2 has no incentive to decrease its price, that is,

$$\mu(p_1^*(q_h), p_2)q_h + (1 - \mu(p_1^*(q_h), p_2))q_\ell - p_2 \leq q_\ell - p_1^*(q_h), \quad p_2 < p_2^*(q_h).$$

For instance, $\mu(p_1^*(q_h), p_2) = 0$ for all $p_2 < p_2^*(q_h)$; if the high-quality entrant would reduce his price, consumers would believe that he sells low quality. Also, $p_1^*(q_h) \leq c_h$ must hold, because otherwise the entrant could profitably deviate with a price below the incumbent's price (with

[13]E.g., in the case of technically complicated goods, consumers may know that firms have the ability to assess each others' goods, whereas consumers themselves are at an informational disadvantage.

the purpose to mimic a low-quality seller). Accordingly, we have an equilibrium. Firm 1's profits equal $\Pi_1^* = \alpha(p_1^*(q_h) - c_\ell)$; higher than in any equilibrium in the model of the previous section. Accordingly, one might conclude that having more information can be beneficial for the incumbent.

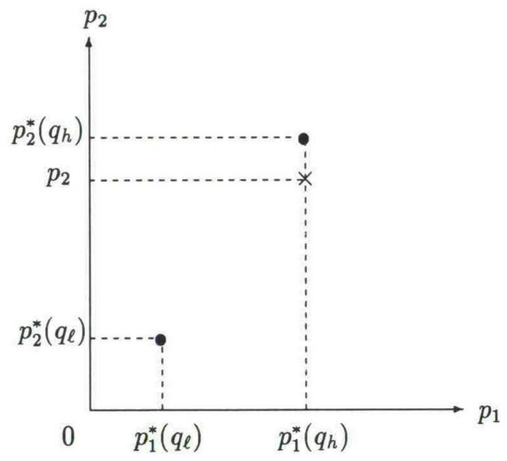

Figure 1: *A separating equilibrium*

However, the beliefs supporting the equilibrium in the example above raise serious doubts. If firm 2 slightly decreases its price to p_2 (see figure 1), a consumer who observes $(p_1^*(q_h), p_2)$ can deduce the entrant's quality from the incumbent's price. To see this, notice that the entrant knows that the incumbent observes q_2, and that consumers realize this. Since $p_1^*(q_\ell) \neq p_1^*(q_h)$, the incumbent's price remains informative about the entrant's type if the entrant deviates. Consumers may therefore reason that firm 1 would not have selected $p_1^*(q_h)$ if firm 2's quality is low. Consequently, prices $(p_1^*(q_h), p_2)$ should make consumers believe that firm 2 sells high quality. Since $q_h - p_2 > q_\ell - p_1^*(q_h)$, the entrant can "free ride" on the incumbent's signal.[14]

[14]The concept of sequential equilibrium does not eliminate the equilibrium in the example. Consider, for the sake of argument, discrete prices (the formal

The example demonstrates that the equilibrium notion needs further refinement. Bagwell and Ramey (1991) give a similar example (in a limit-pricing model with multiple incumbents), which suggests that "free riding on the rival's signal" is a general problem when there is common information. They formulate a restriction on beliefs for signaling games with common information ("unprejudiced" beliefs).[15] For convenience, I use a different but equivalent formulation of their criterion. To do so, a definition is given:

Definition *In an equilibrium with prices $p_1^*(q_2)$ and $p_2^*(q_2)$, $q_2 \in \{q_\ell, q_h\}$, price vector (p_1, p_2) is said to be weakly consistent with $q_2 \in \{q_\ell, q_h\}$ if there exists an $i \in \{1,2\}$ such that $p_i = p_i^*(q_2)$.*

In the rest of this chapter, beliefs in a perfect Bayesian equilibrium have to satisfy assumption 3 and the following criterion:

Assumption 4 *Let equilibrium prices $p_1^*(q_2)$ and $p_2^*(q_2)$, $q_2 \in \{q_\ell, q_h\}$, be given.*

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definition of sequential equilibrium only applies to games with finite strategy spaces). Suppose that the set of possible prices for firm i is $\{p_i^*(q_\ell), p_i^*(q_h), p_i\}$, for some $p_i \in (p_i^*(q_\ell), p_i^*(q_h))$. We will check whether the equilibrium strategies $p_i^*(\cdot)$ satisfy the consistency requirement of sequential equilibrium. If $q_2 = q_\ell$, let firm i tremble (choose each price different from $p_i^*(q_\ell)$) with probability $\varepsilon > 0$. If $q_2 = q_h$, let firm 1 tremble with probability ε, and firm 2 with probability ε^3. What should a consumer who observes prices $(p_1^*(q_h), p_2)$ believe? Beliefs defined by Bayes' rule from the set of completely mixed strategies are $\mu^\varepsilon(p_1^*(q_h), p_2) = [\alpha(1-2\varepsilon)\varepsilon^3]/[\alpha(1-2\varepsilon)\varepsilon^3 + (1-\alpha)\varepsilon^2]$. Now $\lim_{\varepsilon \to 0} \mu^\varepsilon(p_1^*(q_h), p_2) = 0$, i.e., the consistency requirement is satisfied. As argued in Bagwell and Ramey (1991), requiring that all trembles have the same magnitude would eliminate the equilibrium.

[15]Bagwell and Ramey (1991) provide a somewhat different motivation for their beliefs restriction. In my example, their argument would be that consumers observing $(p_1^*(q_h), p_2)$ should believe that the entrant's quality is high because then one deviation instead of two occurred; consumers should not be "prejudiced" in believing that any deviation is more likely than any other. Their notion of unprejudiced sequential equilibrium requires that a deviant price pair is rationalized with the fewest deviations.

(i) Consider prices $p_1, p_2 \in [c_\ell, q_\ell]$. *If* (p_1, p_2) *is weakly consistent with* q_ℓ*, but not with* q_h*, then* $\mu(p_1, p_2) = 0$.
(ii) Consider prices $p_1 \in [c_\ell, q_\ell]$ *and* $p_2 \in [c_h, q_h]$. *If* (p_1, p_2) *is weakly consistent with* q_h*, but not with* q_ℓ*, then* $\mu(p_1, p_2) = 1$.

Assumption 4 explicitly takes into account the common information aspect of the game. In the example above, $(p_1^*(q_h), p_2)$ is weakly consistent with q_h, but not with q_ℓ. Consequently, after observing equilibrium price $p_1^*(q_h)$ and deviation p_2, consumers believe that the entrant sells high quality. Since it is sufficient to pin down out-of-equilibrium beliefs only for slight deviations, a weaker formulation of the refinement will also satisfy.

The appendix derives necessary conditions on informative equilibrium prices (lemmas 1-3). I will briefly discuss some of them. First, if the incumbent deters entry of a high-quality seller, then the incumbent's price must be uninformative, that is, $p_1^*(q_\ell) = p_1^*(q_h)$. This result generalizes the example above and is a consequence of assumption 4. An informative price strategy by firm 1 that deters entry cannot occur in equilibrium, since it allows a high-quality entrant to convince consumers of high quality and attract consumers. An implication is that an incumbent who wants to adopt a "tough" posture (in the sense of making entry difficult) should employ a strategy that does not convey information about the entrant. Second, if a high-quality seller captures the market, then $p_1^*(q_\ell) \geq p_1^*(q_h)$; the incumbent sets an equally or more aggressive price if it faces a high-quality rival.

Proposition 3 *Under assumptions 3 and 4, for any* δ*, there exist exactly two separating equilibria:*
(i) If $\delta > \delta_1$ *then there exists a separating equilibrium in which a high-quality firm enters, and* $p_1^* \equiv p_1^*(q_\ell) = p_1^*(q_h) = c_\ell$, $p_2^*(q_\ell) = c_\ell$*, and* $p_2^*(q_h) = c_\ell + q_h - q_\ell$*;* $\Pi_1^* = 0$ *and* $\Pi_2^* = \alpha(c_\ell + q_h - q_\ell - c_h)$*; the first-best welfare level* W^{FB} *is attained.*
(ii) If $\delta \leq \delta_1$ *then there exists a separating equilibrium in which the incumbent deters entry of a high-quality firm, and* $p_1^* \equiv p_1^*(q_\ell) = p_1^*(q_h) =$

c_ℓ, $p_2^*(q_\ell) = c_\ell$, and $p_2^*(q_h) = c_\ell + q_h - q_\ell$; $\Pi_1^* = \Pi_2^* = 0$; since $W = q_\ell - c_\ell$, an inefficiency exists.

(iii) For any δ there exists a separating equilibrium in which each type of firm enters (i.e., consumers visit and buy from each type of firm 2); in this equilibrium $p_1^*(q_\ell) = c_\ell + q_h - q_\ell$, $p_1^*(q_h) = c_\ell$, $p_2^* \equiv p_2^*(q_\ell) = p_2^*(q_h) = c_\ell + q_h - q_\ell$; $\Pi_1^* = 0$ and $\Pi_2^* = c_\ell + q_h - q_\ell - c_h$; the first-best welfare level W^{FB} is attained.

Proof: (i) For necessary conditions on the prices when a high-quality firm enters, see lemmas 1 and 3 in the appendix. Given that $p_1^* \equiv p_1^*(q_\ell) = p_1^*(q_h)$, the proof of proposition 1 (i) applies to show that $\delta > \delta_1$ is necessary and sufficient. Beliefs $\mu(p_1, p_2^*(q_\ell)) = 0$ and $\mu(p_1, p_2^*(q_h)) = 1$, $\forall\, p_1$, satisfy the refinement criterion.

(ii) For necessary conditions on the prices when entry is deterred, see lemmas 1 and 2. Since $p_1^* \equiv p_1^*(q_\ell) = p_1^*(q_h)$, the proof of proposition 1 (ii) applies to show that $\delta \leq \delta_1$ is necessary and sufficient. As in (i), beliefs satisfy assumptions 3 and 4.

(iii) See lemmas 1 and 3. One can support the equilibrium prices, for any value of δ, with beliefs $\mu(p_1^*(q_\ell), p_2) = 0\ \forall\, p_2$; $\mu(p_1^*(q_h), p_2) = 1\ \forall\, p_2$; $\mu(p_1, p_2^*) = 1\ \forall p_1 < p_1^*(q_\ell)$; and $\mu(p_1, p_2^*) = 0\ \forall p_1 \geq p_1^*(q_\ell)$. If consumers do not visit firm 2 in equilibrium, then firm 2 can slightly decrease its price and attract consumers, a contradiction. □

In parts (i) and (ii) of the proposition, the incumbent's price is uninformative. Accordingly, search costs play the same role as in the model of the previous section. Part (iii) of proposition 3 shows that, contrary to setting I, for any value of δ there exists a separating equilibrium with entry. In this equilibrium, the incumbent's price reveals the entrant's type to consumers. The reason that search costs do not play a role is that a low-quality entrant by itself cannot mimic a high-quality type, since the incumbent's price would still inform consumers that the entrant sells low quality. The incumbent charges a relatively high price to signal that the entrant sells low quality, and a relatively low price in the opposite case.[16] Note that the first-best welfare level is attained in this outcome.

3.4.3 Pooling Equilibria

Any pooling equilibrium of the model in the previous section is also an equilibrium in this model (the only difference is that assumption 1 has been dropped). By and large, the intuition behind proposition 2 applies – see the discussion of condition (7) in the previous section. As in proposition 2, "entry" means that each type of new firm captures the market. Because of the larger degree of freedom in defining consumer beliefs out of equilibrium, additional pooling equilibria may exist. In particular, pooling equilibria exist for any $\alpha \in (0,1)$.

Proposition 4 *Under assumptions 3 and 4, pooling equilibria (with and without entry) exist if and only if* $\delta \le \delta_1$*:*
(i) If entry occurs then $p_1^* \in [c_\ell, q_\ell - (q_h - q_\ell)/(1-\delta)]$ *and* $p_2^* \in [c_h, c_\ell + q_h - q_\ell]$ *such that* $q_\ell - p_1^* \le \alpha q_h + (1-\alpha)q_\ell - p_2^*$ *and (7);* $\Pi_1^* = 0$ *and* $\Pi_2^* = p_2^* - \alpha c_h - (1-\alpha)c_\ell$*; the first-best welfare level* W^{FB} *is attained.*
(ii) If entry is deterred then $p_1^* = c_\ell$ *and* $p_2^* \in [c_h, c_\ell + q_h - q_\ell]$ *such that* $p_2^* \ge c_\ell + \alpha(q_h - q_\ell)$ *and (7);* $\Pi_1^* = \Pi_2^* = 0$*; since* $W = q_\ell - c_\ell$*, an inefficiency exists.*

Proof: See the appendix.

[16] There is an argument against this equilibrium. In the spirit of Grossman and Perry's (1986) perfect sequential equilibrium, beliefs $\mu(p_1, p_2^*) = 1$ for $p_1 \in (p_1^*(q_h), p_1^*(q_\ell))$ are not reasonable. Since firm 1 attracts no consumers in equilibrium, each "type" of incumbent has the same incentive to select a price $p_1 < p_1^*(q_\ell)$. Therefore after a deviation by firm 1, consumers should not draw any conclusion about the entrant's quality: $\mu(p_1, p_2^*) = \alpha$. Then firm 1 is able to attract consumers by deviating.

3.4.4 The Role of the Incumbent's Information

By comparing settings I and II, one can assess whether the incumbent benefits from knowing the entrant's quality (and the entrant and consumers knowing that the incumbent knows, and so forth). If one considers separating equilibria, for any level of search costs there exists an additional equilibrium in setting II (see proposition 3 (iii)). In this equilibrium, consumers visit both types of the entrant. Since in setting I, entry cannot occur if search costs are high (see proposition 1 (ii)), an informed incumbent may help the entrant to persuade consumers to visit it. From a welfare point of view, common information may restore efficiency for sufficiently high search costs (compare propositions 1 (ii) and 3 (iii)).

In setting II, there exist pooling equilibria with and without entry for a wider array of parameter values. One cannot, however, draw clear-cut conclusions concerning the possibilities of entry. Under common information, however, it is possible that if entry occurs the entrant charges a higher price than in any pooling equilibrium without common information. As a consequence the incumbent's additional information may increase the entrant's profits and decrease consumers' surplus.

The results of the analysis imply that the incumbent cannot benefit from observing the entrant's quality. At first sight, this result may look surprising. One would perhaps expect that it would be advantegous for the incumbent to have this information.[17] Intuitively, the entrant, who knows that the incumbent is informed, and knows that consumers know this, has an incentive to exploit informative strategies of the incumbent. The role played by assumption 4 implies a caveat – namely, that without the assumption, information about an entrant could be valuable to the incumbent (as shown in the opening example of this section).

[17] For instance, Bagwell (1990) presumed (in a model with experience goods, see the discussion in the previous section) that "[...] the entrant would be worse off if its type were known to the incumbent" (footnote 4, p. 210).

3.5 Conclusion

To conclude, I will briefly recapitulate some particular signaling possibilities in the model. First, in markets for search goods, a high price can signal high quality. The intuition is that a low-quality entrant is discouraged from mimicking a high-quality type by consumers' credible threat to visit the incumbent should they find out that quality is low.

Second, if the incumbent can observe the entrant's type, it is optimal not to take advantage of this opportunity. The entrant, who knows that the incumbent can observe its type and that consumers realize this, faces less difficulty in convincing consumers of high quality if the incumbent's strategy contains information. In particular, if the incumbent's price is informative then the entrant can circumvent lock-in effects and entry is possible for any level of search costs.

An interesting extension of the model is to consider the choice of location as a quality signal. Nelson (1970) already argued that stores selling search goods have an incentive to cluster. Recall that a price such that a consumer who would observe low quality in the entrant's store would visit the incumbent signals high quality. Thus, if search costs are low, consumers are more easily convinced of high quality. One can endogenize search costs by having the entrant choose its location. An interesting question is why sellers often locate near to each other, despite increased competition; an example is a fruit and vegetables market.

Another direction for further research is to allow the incumbent to spy on an entrant to observe its quality. This information may, however, be of value to the incumbent. The reason is that if the entrant is not sure whether it has been spied upon, it cannot rely on the incumbent's strategy to signal its type.

Appendix

Proof of proposition 2:

In any pooling equilibrium, condition (7) must hold (see section 3.3). Also, a high-quality entrant must not be able to offer a more favorable deal than the incumbent by charging a price that convinces consumers of high quality, that is, $q_h - p_2 \leq q_\ell - p_1^*$ for all $p_2 \geq q_\ell - \delta(q_\ell - p_1^*)$. Equivalently,

$$p_1^* \leq q_\ell - \frac{q_h - q_\ell}{1-\delta}. \tag{8}$$

There exists a price $p_1^* \geq c_\ell$ satisfying (8) if and only if $\delta \leq \delta_1$.

(i) The entrant attracts consumers only if $q_\ell - p_1^* \leq \alpha q_h + (1-\alpha) q_\ell - p_2^*$. If $p_1^* > c_\ell$, then firm 1 has no incentive to decrease its price if $q_\ell - p_1 \leq \alpha q_h + (1-\alpha)q_\ell - p_2^*$ for all $p_1 \in (c_\ell, p_1^*)$. Equivalently, $p_2^* \leq c_\ell + \alpha(q_h - q_\ell)$. The latter condition must also hold if $p_1^* = c_\ell$. Since any price $p_2 < c_h$ signals low quality, $p_2^* \geq c_h$. Combining these two constraints, it follows that $\alpha \geq (c_h - c_\ell)/(q_h - q_\ell)$. There exists a $p_1^* \geq c_\ell$ that satisfies (8) if and only if $\delta \leq \delta_1$. Since $p_2^* \leq c_\ell + \alpha(q_h - q_\ell) < c_\ell + q_h - q_\ell$ and $p_1^* \geq c_\ell$, a sufficient condition for (7) is $c_\ell + q_h - q_\ell \leq q_\ell - \delta(q_\ell - c_\ell)$. The latter condition is equivalent to $\delta \leq \delta_1$. The equilibrium outcome can be supported by beliefs $\mu(p_1^*, p_2) \leq \alpha$ for all $p_2 \in (c_h, q_\ell - \delta(q_\ell - c_\ell))$.

(ii) It must be that $p_1^* = c_\ell$ (see section 3.3). The incumbent cannot attract consumers by a price increase only if $q_\ell - p_1^* = \alpha q_h + (1-\alpha) q_\ell - p_2^*$, so that $p_2^* = c_\ell + \alpha(q_h - q_\ell)$. Since $p_2^* \geq c_h$, it follows that $\alpha \geq (c_h - c_\ell)/(q_h - q_\ell)$. Inequality (8) holds if and only if $\delta \leq \delta_1$. As in (i), $\delta \leq \delta_1$ implies (7). The equilibrium outcome can be supported by beliefs $\mu(p_1^*, p_2) \leq \alpha$ for all $p_2 \in (c_h, p_2^*) \cup (p_2^*, q_\ell - \delta(q_\ell - c_\ell))$. □

Lemma 1 *(Necessary condition for separating equilibria)*
$q_\ell - p_1^*(q_h) = q_h - p_2^*(q_h)$.

Proof: If $q_\ell - p_1^*(q_h) > q_h - p_2^*(q_h)$, then firm 1 can increase its price, a contradiction. Therefore, suppose $q_\ell - p_1^*(q_h) < q_h - p_2^*(q_h)$. If $p_1^*(q_\ell) \neq p_1^*(q_h)$, then there exists a price $p_2 > p_2^*(q_h)$ such that $q_\ell - p_1^*(q_h) \leq$

$q_h - p_2$ and $p_2 \neq p_2^*(q_\ell)$, that is, $(p_1^*(q_h), p_2)$ is weakly consistent with q_h, but not with q_ℓ. According to the refinement criterion, $\mu(p_1^*(q_h), p_2) = 1$. Therefore, firm 2 can increase its price and attract consumers, a contradiction. Consequently, $p_1^* \equiv p_1^*(q_\ell) = p_1^*(q_h)$. Since consumers visit the entrant in case of high quality, a low-quality entrant must not be able to mimic a high type, that is, $q_\ell - p_2^*(q_h) < \delta(q_\ell - p_1^*)$ must hold. But then any price $p_2 > p_2^*(q_h)$ satisfies $q_\ell - p_2 < \delta(q_\ell - p_1^*)$. By assumption 3, a high-quality entrant has an incentive to increase its price, a contradiction. □

Lemma 2 *(Necessary conditions for separating equilibria)*
Suppose that consumers observe $(p_1^*(q_h), p_2^*(q_h))$. If they visit firm 1 then
(i) $p_1^* \equiv p_1^*(q_\ell) = p_1^*(q_h)$, and
(ii) $p_1^* = c_\ell$, $p_2^*(q_\ell) = c_\ell$ and $p_2^*(q_h) = c_\ell + q_h - q_\ell$.

Proof: (i) Suppose that $p_1^*(q_\ell) \neq p_1^*(q_h)$. By lemma 1 and (1), $p_2^*(q_h) = p_1^*(q_h) + q_h - q_\ell > c_h$. There exists a price $p_2 < p_2^*(q_h)$ such that $(p_1^*(q_h), p_2)$ is weakly consistent with q_h, but not with q_ℓ. Therefore, $\mu(p_1^*(q_h), p_2) = 1$ and firm 2 can attract consumers by decreasing its price – a contradiction.
(ii) If $p_1^* > c_\ell$, then in case of $q_2 = q_\ell$, the entrant captures the market at a price $p_2^*(q_\ell)$ just below p_1^*. There exists a price $p_1 \in (c_\ell, p_2^*(q_\ell))$ such that $(p_1, p_2^*(q_\ell))$ is weakly consistent with q_ℓ, but not with q_h. Hence $\mu(p_1, p_2^*(q_\ell)) = 0$, and firm 1 can increase its profits by undercutting firm 2 after observing that $q_2 = q_\ell$, a contradiction. Therefore, $p_1^* = c_\ell$. Moreover, $p_2^*(q_\ell) = c_\ell$, since otherwise firm 1 would have an incentive to increase $p_1^*(q_\ell)$. From lemma 1 it follows that $p_2^*(q_h) = c_\ell + q_h - q_\ell$.
□

Lemma 3 *(Necessary conditions for separating equilibria)*
Suppose that consumers observe $(p_1^*(q_h), p_2^*(q_h))$. If they visit firm 2 then
(i) either $p_1^*(q_\ell) = c_\ell$ and $p_2^*(q_\ell) = c_\ell$; or $p_1^*(q_\ell) = c_\ell + q_h - q_\ell$ and

$p_2^*(q_\ell) = c_\ell + q_h - q_\ell$, and
(ii) $p_1^*(q_h) = c_\ell$ and $p_2^*(q_h) = c_\ell + q_h - q_\ell$.

Proof: (In reverse order) (ii) Notice that $p_1^*(q_h) = c_\ell$, otherwise firm 1 could attract consumers by decreasing its price. By lemma 1, $p_2^*(q_h) = c_\ell + q_h - q_\ell$.
(i) First, suppose that $p_2^*(q_\ell) \neq p_2^*(q_h)$. If $q_\ell - p_1^*(q_\ell) > q_\ell - p_2^*(q_\ell)$ then, by the refinement criterion, firm 1 can increase its price. If $q_\ell - p_1^*(q_\ell) < q_\ell - p_2^*(q_\ell)$, then firm 2 can increase its price. Therefore, $q_\ell - p_1^*(q_\ell) = q_\ell - p_2^*(q_\ell)$. From similar arguments it follows that $p_1^*(q_\ell) = c_\ell$ and $p_2^*(q_\ell) = c_\ell$.
Second, suppose that $p_2^*(q_\ell) = p_2^*(q_h)$. Therefore, $p_1^*(q_\ell) > p_1^*(q_h)$. If $q_\ell - p_1^*(q_\ell) > q_\ell - p_2^*(q_\ell)$ then the incumbent has an incentive to pretend that he observed a low-quality entrant by selecting $p_1^*(q_\ell)$ if the entrant's actual quality is high. If $q_\ell - p_1^*(q_\ell) < q_\ell - p_2^*(q_\ell)$, then firm 2 can increase its price. It follows that $q_\ell - p_1^*(q_\ell) = q_\ell - p_2^*(q_\ell)$ (and consumers visit the entrant). Accordingly $p_1^*(q_\ell) = c_\ell + q_h - q_\ell$. □

Proof of proposition 4:
In any pooling equilibrium, (7) and (8) must hold. Firm 1 should not have an incentive to deviate with some price $p_1 > c_\ell$. Let $\mu(p_1, p_2^*) = 1$ for such a deviation, so that it is sufficient to require $q_\ell - p_1 \leq q_h - p_2^*$ for all $p_1 > c_\ell$. Equivalently, $p_2^* \leq c_\ell + q_h - q_\ell$. Entry occurs only if $q_\ell - p_1^* \leq \alpha q_h + (1-\alpha)q_\ell - p_2^*$. Entry is deterred only if $q_\ell - p_1^* \geq \alpha q_h + (1-\alpha)q_\ell - p_2^*$. Also, if entry is deterred then $p_1^* = c_\ell$. The equilibrium outcomes can be supported by beliefs $\mu(p_1^*, p_2)$ similar to those in the proof of proposition 2. □

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Chapter 4

Delegation of Responsibility in Organizations

4.1 Introduction

The principal-agent literature studies optimal reward structures for an agent who dislikes exerting effort (see Hart and Holmström (1987) for a survey). Typically in this literature, the principal is uncertain about either the agent's productivity or the level of effort exerted by the agent. The principal's problem then is to maximize profits by designing an optimal "carrot," that is, a pecuniary incentive scheme that induces the agent to work as hard as possible, given the informational constraints.

In this chapter, I explore a principal-agent relationship in which the agent derives private benefits from exerting effort. Private benefits may include job satisfaction (the agent *enjoys working*), the acquisition of professional experience, and so on.[1] The principal can appeal to the agent's private benefits by giving him a say in the job he has to do.

Among a number of candidate projects, one project that the agent will have to implement has to be selected. The agent's preferences among the projects are ex ante unknown, and he has to incur a private

[1]Some more examples are: a sense of accomplishment and achievement, career concerns, and perks on the job.

cost (e.g. effort or time) to find out his personal gains. The agent will work harder on projects that yield him higher private benefits. The principal can either impose a project, or delegate responsibility to choose one to the agent. In particular, the principal can determine a subset of the possible projects so that the agent has discretion to pick a project in this choice set.[2] When the principal has decided how much discretion the agent gets, the agent decides to get informed or not about his private benefits, and then recommends a project to the principal. The agent is allowed to implement his proposal if it was included in his choice set.[3]

Where will the principal draw the line around responsibility? By imposing a project, the principal is certain that his preferred project will be implemented. A consequence is, however, a lack of initiative by the agent. Indeed, since it is unlikely that the project will yield significant private benefits for the agent, he has no incentive to get informed. The result is that the agent will not work very hard. Giving the agent more discretion results in initiative: the agent will get informed and recommend his preferred project. The agent's proposal may not be the principal's preferred project, but the agent will work hard if he is allowed to implement his recommendation.

So although the superior has formal authority to select a project, it may be in his interest to implement one that generates interest from his subordinate. Consequently, the agent may to some extent have real authority (see also Tirole (1994)).

An important observation in the model is the following. To have an

[2]In the model, the principal can choose a more general mechanism; the optimal mechanism corresponds (roughly) to a choice set for the agent.

[3]The following quote illustrates a central question: "The issue [...] is where to draw the line around responsibilities and [...] freedom. I agree that it's important to delegate responsibility and empower people throughout the organization, but you also have to communicate clearly what the boundaries are around their jobs." (N. Poole, Executive Vice President of L.L. Bean of Freeport, in Continental Bank (1993), p. 50.)

incentive to collect information, the agent may need a level of discretion that is larger than the principal would give him if getting informed would be costless. In this case the agent's proposal need not be optimal ex post (from the principal's point of view), although the agent's choice set is optimal ex ante. In a world in which a court could enforce contracts that specify the agent's discretion, there would be no problem. However, if one thinks of hierarchies in organizations, such contracts seem to be the exception rather than the rule. Informally, the principal only promises to accept any proposal in the agent's choice set.

Commitment problems may disappear if the principal can build a reputation for not breaking promises.[4] A question addressed in this chapter is how the principal can credibly commit himself when he cannot establish such a reputation. As was already noticed by Schelling (1960), a solution may be to write a contract with a third party. In my model, profit-sharing with a third party via a renegotiation-proof contract can give the principal incentives not to abuse his authority. Such a profit-sharing agreement can be interpreted as a financial contract. For instance, an investor buys the right to receive a share of the profits (dividends). Alternatively, the principal's superior (e.g. the firm's CEO) implements an incentive scheme for the principal.

The principal and the third party may refrain from renegotiating because there is an informational asymmetry.[5] At the time of renegotiation, only the principal knows the agent's proposal. The optimal contract is such that the third party cannot infer the proposal at this

[4]Consider a repeated-game setting. If some ex post sub-optimal project is proposed by the agent, the principal faces a tradeoff between (i) imposing a superior project and decreasing the agent's future incentives to recommend projects, and (ii) following up the recommendation and increasing future incentives to recommend projects. See Tirole (1988, ch. 6), for a survey of the theory of repeated interaction. On reputation, trust, and corporate culture, see Kreps (1990).

[5]See also Dewatripont (1988), who studies a model in which an incumbent uses a labor contract to deter entry. Such a contract may be renegotiation-proof, and therefore imply a credible commitment, under an informational asymmetry between the incumbent and his workers.

stage. Hence, he is not sure whether there is an allocative gain when renegotiating; the principal might be trying to realize a gain at the third party's disadvantage. Therefore, he may refuse an offer to renegotiate.

In the literature on organization and management, it is well-known that intrinsic rewards (e.g. job satisfaction) may be very important.[6] For instance, if a researcher is fascinated by a problem, he will automatically work hard, and it is then practically impossible to induce him to work harder by relating his pay to, say, the number of papers he writes. Actually, there is a debate going on in the management literature in which performance-related pay is under heavy fire.[7] Besides that payment schemes may be costly to implement, it is put forward that they may demotivate people.[8] The intention of this chapter is not to participate in this debate, but instead to complement the principal-agent literature by investigating how a superior can motivate his subordinate by appealing to his private benefits.

Aghion and Tirole (1994) study the endogenous separation of formal authority (the right to choose a project) and real authority (the effective choice of a project).[9] A principal and an agent each incur a cost to get informed about their (possibly unaligned) preferences over some projects. The principal can give the agent real authority by not having incentives to get informed himself, so that the agent becomes more eager to get informed, while the principal's formal authority decreases.

[6]As argued by Dessler (1986), "Few rewards are as powerful as the sense of accomplishment and achievement that come from doing a job that one genuinely wants to do [...]" (p. 254).

[7]See e.g. Kohn (1993), and the references to empirical evidence therein. One of the basic objections is that "[...] workers are much more influenced by [...] the intrinsic interest of their work than by crass material rewards" (*The Economist* (1994), p. 69).

[8]A possible reason, supported by empirical evidence, is that monitoring (which may be needed to implement a payment scheme) reduces effort because it is perceived as an indication of distrust (Frey (1993)).

[9]Simon (1951) addressed why an agent may be willing to give a principal authority (the right to select actions that affect the agent) over his behavior by entering an employment relationship.

An alternative way to motivate the agent to learn the projects' payoffs is to "make him his own boss," that is, split up the firm. In my model, the principal's concern is how much responsibility he should delegate to the agent, instead of whether he should get informed himself, or split up the firm. Also, in my model, empowering the agent alleviates two moral hazard problems: it motivates the agent to get informed in order to recommend a project, and to work hard.

Also (but less closely) related are Armstrong (1995) and Holmström (1984). Each of those papers considers a principal who can delegate decision-making to an agent with expert information. Their main result is that the agent gets more discretion when he has more information or when his (expected) preferences are more aligned with the principal's.

Athey et al. (1994) analyze the allocation of decisions among two agents (e.g. a foreman and a manager), in an organization that faces uncertainty (e.g. concerning demand conditions and defective output of machines). In different states of nature, the agents differ in their decision-making effectiveness (e.g. due to talent, or because the quality of a decision decreases as an agent gets more responsibility). Initially, a subset of the possible states has to be chosen. Next, a state is realized by nature and a decision must be made. If the state is in that set, then the foreman makes the decision; otherwise, the manager decides. Besides that their paper focuses on quite different issues, a main difference with my paper is that Athey et al. do not consider agency problems.

Jensen (1986) argued that debt repayments or positive dividends may reduce managers' overuse of resources when a firm generates free cash flow. Ravid and Sudit (1994) derive related findings when a manager derives direct utility from his exercise of power, which is associated with the quantity of resources at his disposal. In my model, since he has formal authority a manager can always impose which project his subordinate has to implement; the manager has power over his subordinate's labor. Although the exercise of power itself does not yield any utility, the manager sometimes wants to abuse the power he has; profit-sharing may prevent him from doing so. In contrast, Ravid and Sudit consider (under conflicts of interest between managers and shareholders) financial contracts that resolve inefficiencies due to power-seeking.

The result that commitment can be obtained by contracting with a third party illustrates Williamson's (1985) idea that low-powered incentives may alleviate agency problems. Whereas Williamson argues that high-powered incentives may lead to asset utilization losses and accounting manipulations, my model gives an alternative motive for using low-powered incentive schemes (which result from profit-sharing with an investor), namely the issue of the superior's credibility.

The model is presented in the following section, as well as some examples. Under the assumption that the principal can commit himself, section 4.3 derives the optimal level of discretion for the agent. I show that time-inconsistency may, but need not, pose problems if the principal cannot commit. Section 4.4 investigates how a contract with a third party may solve the credibility problem. Section 4.5 concludes. An appendix demonstrates why using pecuniary rewards may have little effect.

4.2 The Organization

Consider a hierarchy (or organization) that consists of a principal called P, and an agent called A. The hierarchy can implement one out of $n \geq 2$ projects. The principal's role is to either pick a project or delegate the choice of a project to the agent. Once a project has been selected, the agent executes (or implements) it.

The principal's benefits of project k, also be called profits, are denoted by $\Pi_k(e)$, where $e \geq 0$ is the agent's effort in executing the project. The effort of the agent may be observable, and even verifiable. However, it will not be included in a contract (see below).

Assumption 1 $\Pi_k(e)$ *(i) is decreasing in k, for all e; (ii) is strictly* *increasing in e, for all k; and (iii) satisfies* $\Pi_k(e) > 0$, *for all k and* $e > 0$.

By assumption 1, for a given effort level the principal prefers project 1. Also, all the projects are profitable.

The agent derives benefits $U(b_k, e) \geq 0$ from project k if he exerts effort e, where b_k denotes his private benefits of project k. Private benefits may represent intrinsic rewards such as job satisfaction, challenge, and a sense of accomplishment and achievement, but one can also think of perks on the job, the acquisition of professional experience, career concerns, and so on.

Assumption 2 $U(b, e)$ *(i) is strictly increasing in b, for all e; (ii) is strictly concave in e, for all b; and (iii) satisfies* $\partial^2 U(b, e)/(\partial b \partial e) > 0$.

By assumption 2 (iii), private benefits and effort are complementary, that is, the agent's optimal effort level is increasing in the level of his private benefits.

Nature selects the agent's private benefits $b_1, \ldots, b_n$ according to a distribution $\Pr(b_i = \overline{b}$ and $b_j = \underline{b},\ \forall j \neq i) = \alpha_i$, where $\sum_i \alpha_i = 1$ and $\overline{b} > \underline{b} \geq 0$. Thus there is one most-preferred project for the agent; he is indifferent among the other projects. Suppose furthermore that $\alpha_1 \geq \alpha_j$ for all j, that is, there is not too much divergence of P's ranking of the projects and A's ex ante preferences.[10]

The realization of A's private benefits can only be observed by A. However, he has to incur a private cost $F > 0$ (e.g. time and effort) to do so. Whether A gets informed is unverifiable. An example is a scientist, whose job satisfaction depends on the originality of his work. When choosing among research topics, he can get informed by going through recent literature to see which topic is the most promising one.[11]

[10]These assumptions facilitate the exposition and analysis; they are not crucial for the insights.

[11]Alternatively, F may be the cost of scanning the labor market for career opportunities: once the agent has incurred F, he immediately sees which project he

To simplify the analysis, it will be assumed that the agent receives a constant salary equal to his reservation wage, which is normalized to zero. One can justify this assumption in different ways. Firstly, money may be a bad motivator. For instance, the agent is infinitely risk averse to income. Secondly, a fixed wage may be imposed. For example, the hierarchy is part of a larger organization in which top management finds it too costly to condition salaries on all possible contingencies that occur at lower levels in the organization. Alternatively, fixed wages may be due to labor union influence. A consequence of this assumption is that the agent's effort level will not be included in a contract. As argued in an appendix, abstracting from pecuniary incentive schemes does not affect generality when the agent is relatively more responsive to private benefits than to money.[12]

P's delegation decision is described by a mechanism $(x_1, \ldots, x_n)$, where $x_i \in [0, 1]$ for all $i = 1, \ldots, n$. The mechanism has the following interpretation. If A recommends some project k, then he is allowed to implement this project with probability x_k, and has to implement project 1 with probability $1 - x_k$.[13] So

$$x_k = \Pr(\text{project } k \text{ is implemented} \mid A \text{ proposed project } k).$$

The mechanism $(1, 0, \ldots, 0)$ corresponds to P imposing project 1, which is his preferred project. Under the mechanism $(1, \ldots, 1)$, A has complete responsibility; any project that he recommends will be implemented.

Some simplifying notation is introduced. Let A's optimal effort for a project that yields high private benefits be denoted by $\overline{e} \equiv$

prefers. The fact that F is independent of the number of projects simplifies the analysis without loss of generality.

[12]If the agent responded to monetary incentives, the principal could increase the agent's incentives (i) to observe his private benefits and recommend a project, and (ii) to exert effort (see also Aghion and Tirole (1994)).

[13]One could define $x_{ki} = \Pr(\text{project } i \text{ is implemented} \mid A \text{ proposed } k)$. A mechanism would then be a matrix $(\underline{x}_1, \ldots, \underline{x}_n)$, where $\underline{x}_k = (x_{k1}, \ldots, x_{kn})'$. One can check that the optimal mechanism would satisfy $x_{ki} = 0$ for all $i \neq 1, k$.

$\arg\max_e U(\overline{b}, e)$. Similarly, denote his optimal effort for a bad project by $\underline{e} \equiv \arg\max_e U(\underline{b}, e)$, and his optimal effort when he is uninformed by $e_i^0 \equiv \arg\max_e\{\alpha_i U(\overline{b}, e) + (1 - \alpha_i)U(\underline{b}, e)\}$. Furthermore, denote $\overline{u} \equiv U(\overline{b}, \overline{e})$, $\underline{u} \equiv U(\underline{b}, \underline{e})$, and $u_i^0 \equiv \alpha_i U(\overline{b}, e_i^0) + (1 - \alpha_i)U(\underline{b}, e_i^0)$. Note that by assumption 2, $\overline{e} > e_i^0 > \underline{e}$ and $\overline{u} > u_i^0 > \underline{u}$ for all i.

To make the analysis interesting, I make the following assumption:

Assumption 3 $\alpha_1\overline{u} + (1 - \alpha_1)\underline{u} - u_1^0 < F \leq \overline{u} - u_1^0$.

By assumption 3, the cost that the agent incurs when he learns his private benefits is neither too low, nor too high. This assumption has two important implications. Firstly, the agent does not care about learning the value of b_1 if project 1 is imposed. Secondly, the agent will always get informed if he has complete discretion.

The timing of the game is as follows:

$t = 0$: Nature selects A's private benefits, unobserved by P and A. P chooses $x_i \in [0, 1]$, $i = 1, \ldots, n$, and communicates $(x_1, \ldots, x_n)$ to A.

$t = 1$: A decides whether to learn his private benefits (at cost F).

$t = 2$: A recommends a project k to P.

$t = 3$: Project k is selected with probability x_k, and project 1 is selected with probability $1 - x_k$. Subsequently, A picks an effort level e to execute the selected project.

Examples:

Consider benefit functions $\Pi_k(e) = p(e)B_k$, and $U(b, e) = p(e)b - e$. The values of the projects to P satisfy $B_1 > \ldots > B_n > 0$. Futhermore, $p(\cdot)$ is increasing and concave, $p(0) = 0$ and $\lim_{e\to\infty} p(e) = 1$. Three interpretations are:

1. *Production*: The agent, who derives private benefits from working, takes care of production. The principal sells the product.

B_k is the willingness to pay for a product of type k by a potential customer, given that it completely meets her wishes. In this context $p(e)$ denotes product quality. Accordingly, producing a "perfect" product ($p(e) = 1$) is extremely costly for the agent, and the client is willing to pay $p(e)B_k$ for a product of quality $p(e)$.

2. *Marketing*: The agent performs marketing activities for an existing product, and derives private benefits from being active in a particular market. B_k denotes the size of market k (in each market, consumers are willing to pay a price 1 for the product). Here $p(e)$ is the fraction of the market that is reached as a result of exerting marketing effort e.

3. *Research & Development*: The agent is the researcher, and derives private benefits from realizing a particular innovation. An innovation of type k has patent value B_k. Given an effort level e, an innovation k is realized with probability $p(e)$.

4.3 Optimal Delegation

The equilibrium of the game is calculated by backward induction. Suppose that project k is selected at $t = 3$. Two cases can be distinguished:

(i) A knows the value of b_k. If $b_k = \overline{b}$ then A exerts effort $\overline{e}$. If $b_k = \underline{b}$ then A exerts effort $\underline{e}$.

(ii) A does not know the value of b_k. He exerts effort e_k^0.

At $t = 2$, A recommends a project. If he did not observe his private benefits, he will act in P's interest (because $\alpha_1 \geq \alpha_j$ for all j) and recommend project 1.[14] If A knows his private benefits, then he recom-

[14]Equivalently, one could give A the possibility to make no recommendation, after which P will optimally pick project 1.

mends project k if and only if $b_k = \overline{b}$. Thus the incentive compatibility constraints are trivially satisfied. Given a mechanism $(x_1, \ldots, x_n)$, project k is accepted by P with probability x_k. If rejected, project 1 is chosen.

Setting $x_1 = 1$ (note that this does not impose any restrictions), A will learn his private benefits at $t = 1$ if and only if

$$\sum_{k=1}^{n} \alpha_k (x_k \overline{u} + (1 - x_k)\underline{u}) - F \geq u_1^0,$$

equivalent to

$$\sum_{k=1}^{n} \alpha_k x_k (\overline{u} - \underline{u}) \geq F + u_1^0 - \underline{u}. \tag{1}$$

The principal's delegation problem at $t = 0$ can be split into two problems. The first one is the optimal choice of $(x_1, \ldots, x_n)$, denoted by $(x_1', \ldots, x_n')$, given that A learns his private benefits:

$$\begin{aligned} \Pi^{\text{inf}} \equiv \max_{x_1,\ldots,x_n} \quad & \sum_{k=1}^{n} \alpha_k [x_k \Pi_k(\overline{e}) + (1 - x_k)\Pi_1(\underline{e})] \\ \text{s.t.} \quad & \sum_{k=1}^{n} \alpha_k x_k (\overline{u} - \underline{u}) \geq F + u_1^0 - \underline{u}, \\ & 0 \leq x_i \leq 1, \ i = 1, \ldots, n. \end{aligned} \tag{2}$$

The second problem is the optimal choice of $(x_1, \ldots, x_n)$, denoted by $(x_1^0, \ldots, x_n^0)$, under the restriction that A is not willing to incur the observation cost:

$$\begin{aligned} \Pi^0 \equiv \max_{x_1,\ldots,x_n} \quad & \Pi_1(e_1^0) \\ \text{s.t.} \quad & \sum_{k=1}^{n} \alpha_k x_k (\overline{u} - \underline{u}) < F + u_1^0 - \underline{u}, \\ & 0 \leq x_i \leq 1, \ i = 1, \ldots, n. \end{aligned} \tag{3}$$

The implicit form of the solution of problem (2), as well as the explicit solution of (3), are given in the following lemma. Roughly speaking, the principal chooses a choice set for the agent; a proposal will be implemented if and only if it is in this choice set.

Lemma 1 *(i) Problem (2) is solved by a mechanism* $(x'_1, \ldots, x'_n) = (1, \ldots, 1, x'_\ell, 0, \ldots, 0)$*, for some* $x'_\ell \in [0,1]$ *and* $\ell \in \{2, \ldots, n\}$ *such that (1) holds with equality if* $\Pi_\ell(\overline{e}) < \Pi_1(\underline{e})$.
(ii) Problem (3) is solved by mechanism $(x^0_1, \ldots, x^0_n) = (1, 0, \ldots, 0)$.

Proof: (i) In problem (2), P will select $x'_1 = 1$, because $\Pi_1(\overline{e}) > \Pi_1(\underline{e})$. Moreover, since $\Pi_k(\overline{e}) - \Pi_1(\underline{e})$ is decreasing in k, there exists an $m \in \{1, \ldots, n\}$ such that

$$\Pi_i(\overline{e}) \geq \Pi_1(\underline{e}) \text{ for all } i = 1, \ldots, m,$$

and

$$\Pi_i(\overline{e}) < \Pi_1(\underline{e}) \text{ for all } i = m+1, \ldots, n.$$

Accordingly, P sets $x'_i = 1$ for all $i = 1, \ldots, m$. There are two possibilities.
1. Inequality (1) is satisfied if $x'_i = 0$ for all $i = m+1, \ldots, n$.
2. Inequality (1) is not satisfied if $x'_i = 0$ for all $i = m+1, \ldots, n$. By assumption 3, there exists an $\ell \in \{m+1, \ldots, n\}$ such that (1) holds if $x'_i = 1$, $i = m+1, \ldots, \ell$ and $x'_i = 0$, $i = \ell+1, \ldots, n$. However, since setting $x'_i > 0$ is ex post costly for P if A recommends a project $i \in \{m+1, \ldots, \ell\}$, P will set $x'_\ell \in (0,1]$ such that (1) is binding, that is,

$$x'_\ell = \frac{F + u^0_1 - \underline{u} - \sum_{i=1}^{\ell-1} \alpha_i(\overline{u} - \underline{u})}{\alpha_\ell(\overline{u} - \underline{u})}. \tag{4}$$

(ii) Follows directly from assumption 3. □

The intuition behind lemma 1 (i) is as follows. If A, informed about his private benefits, recommends a project k with $\Pi_k(\overline{e}) \geq \Pi_1(\underline{e})$, then the proposal will be accepted by P. In this case P cares more about A's effort than about his own preferences when comparing project k with project 1. However, in order to give A an incentive to observe his private benefits it may be necessary that P also accepts some "bad" projects, that is, projects for which $\Pi_k(\overline{e}) < \Pi_1(\underline{e})$. Of course, P will accept as few bad projects as possible; when it is necessary to include some of these projects in A's choice set, (1) will hold with equality.

Lemma 1 (ii) follows directly from assumption 3. Problem (3) is trivially solved by giving A no discretion; the agent's choice set contains only project 1.

Proposition 1 *(i) If* $\Pi^{\text{inf}} \geq \Pi^0$ *then* P *chooses a mechanism* $(1, \ldots, 1, x'_\ell, 0, \ldots, 0)$, *where* $\ell \geq 2$ *is given in lemma 1 (i);* A *will learn his private benefits and propose his preferred project.*
(ii) If $\Pi^{\text{inf}} < \Pi^0$ *then* P *selects mechanism* $(1, 0, \ldots, 0)$*;* P *imposes his preferred project and* A *will not learn his private benefits.*

Proof: Giving the agent discretion is optimal if and only if $\Pi^{\text{inf}} \geq \Pi^0$, that is, it is (expectedly) profitable. Therefore, applying lemma 1,

$$x_i^* = \begin{cases} x'_i, & i = 1, \ldots, n \text{ if } \Pi^{\text{inf}} \geq \Pi^0, \\ x_i^0, & i = 1, \ldots, n \text{ otherwise.} \end{cases} \qquad \square$$

The intuition behind proposition 1 is straightforward. Little discretion in project choice results in a lack of initiative: A has no incentive to learn his private benefits. P's most preferred project is implemented, but A exerts an intermediate level of effort. Accordingly, authoritive management demotivates the subordinate, but keeps the superior in control. Much discretion in project choice results in initiative: A will learn his private benefits and recommend his preferred project. The selected project may be suboptimal for P, but A exerts a maximum level of effort if he is allowed to implement his proposal. Thus, "hands-off" management, that is, empowering the subordinate, triggers interest and initiative, but decreases the superior's real authority. The optimal mechanism balances these two effects.

In general, the principal will delegate responsibility to the agent if high effort on some of the principal's less-preferred projects yields higher profits than intermediate effort on his most-preferred project. Accordingly, it becomes more likely that the agent will get discretion if profits of various projects become more responsive to the level of effort exerted by the agent.

For an expositional purpose, one can define the agent's level of discretion as

$$X^* \equiv \tfrac{1}{n}\,(x_1^* + \ldots + x_n^*). \tag{5}$$

Notice that $X \in [\frac{1}{n}, 1]$. A higher level of X corresponds to more responsibility for the agent. In particular, $X = \frac{1}{n}$ correponds to no discretion, and $X = 1$ to total freedom.

What role does the agent's cost of getting informed play? If constraint (1) is not binding, which is typically the case when the cost of getting informed (F) is low, then a small increase in F does not influence the optimal discretion level X^*. Now suppose that F is relatively high, so that (1) is binding. By inspection of (4) it follows that when F slightly increases, X^* will increase as well. However, this is only true as long as Π^{inf} does not drop below Π^0. If this happens, that is, if there is a large increase in F, then the agent loses all his responsibility. Let the threshold level of F be denoted by $\tilde{F}$. Figure 1 demonstrates the dependence between F and X^*.

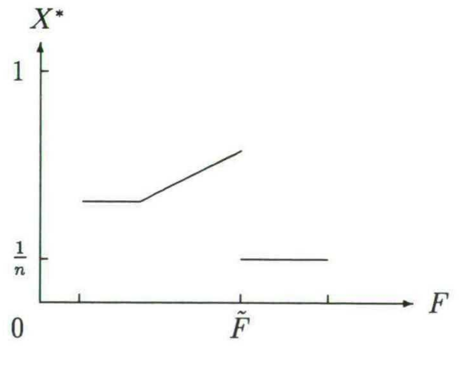

Figure 1: *Optimal discretion and the cost of getting informed*

Example:

Let $\Pi_k(e) = p(e)B_k$, and $U(b,e) = p(e)b - e$, where $B_1 > \ldots > B_n > 0$, $p(\cdot)$ is increasing and concave, and satisfies $p(0) = 0$ and $\lim_{e\to\infty} p(e) = 1$. The number of projects is 3. Suppose that $F = (\alpha_1 + \alpha_2)\overline{u} + \alpha_3\underline{u} - u_1^0$

and $p(\overline{e})B_3 < p(\underline{e})B_1$. Calculations yield that $(x_1', x_2', x_3') = (1, 1, 0)$ and $\Pi^{\text{inf}} = \alpha_1 p(\overline{e})B_1 + \alpha_2 p(\overline{e})B_2 + \alpha_3 p(\underline{e})B_1$. Furthermore, $(x_1^0, x_2^0, x_3^0) = (1, 0, 0)$ and $\Pi^0 = p(e_1^0)B_1$. If $\alpha_1 p(\overline{e})B_1 + \alpha_2 p(\overline{e})B_2 + \alpha_3 p(\underline{e})B_1 \geq p(e_1^0)B_1$ then the optimal delegation scheme is $(x_1^*, x_2^*, x_3^*) = (1, 1, 0)$. Accordingly, the agent finds it worthwile to learn the private benefits of the different projects, so that he can recommend his preferred project.

So far in the analysis, it was implicitly assumed that the principal can commit himself to a mechanism. To see why this assumption is sometimes needed, consider the example above and suppose P is not able to commit himself. Let $p(\overline{e})B_2 < p(\underline{e})B_1$, that is, if the agent recommends project 2, the principal ex post prefers project 1. The mechanism $(x_1^*, x_2^*, x_3^*) = (1, 1, 0)$, however, suggests that the agent's recommendation for project 2 will be followed up by the principal; there is a time-inconsistency problem. This observation naturally leads to the following result, which is immediate after inspection of problem (2):

Proposition 2 *If P cannot commit himself to follow up the A's recommendation, then only mechanisms $(x_1^*, \ldots, x_n^*)$ that satisfy $x_k^* > 0 \Leftrightarrow \Pi_k(\overline{e}) \geq \Pi_1(\underline{e})$, for all k, are credible. Accordingly, credible commitment may be necessary for delegation of responsibility.*

It is obvious that lack of commitment may hurt the principal. In the example above, the only credible mechanism if the principal cannot commit himself is $(x_1^*, x_2^*, x_3^*) = (1, 0, 0)$. Accordingly, expected profits are $\Pi_1(e_1^0) < \Pi^{\text{inf}}$. Since more discretion increases the likelihood that the agent can realize high private benefits, lack of commitment may also hurt the agent.

As figure 1 shows, when the agent's cost of getting informed, F, increases, the agent needs more discretion to have an incentive to take initiative. Therefore commitment problems are in general more severe when F is higher.

4.4 Credible Commitment

In this section I assume that the principal cannot commit himself to carry out a promise that is suboptimal ex post. If a court could enforce the principal's mechanism, there would be no problem: given some proposal k that satisfies $x_k^* > 0$, the agent would never agree on ex post setting $x_k = 0$, that is, imposing a different project. Thus, the principal may have a credibility problem if a court cannot prevent the principal from abusing his authority, which is for instance the case if project implementation is not verifiable by outsiders. If one thinks of hierarchies in organizations, such contractual incompleteness seems to be rather common. The purpose of this section is to find a solution to this credibility problem if the principal has no possibility to build up a reputation for not breaking promises.

Throughout this section it will be assumed that $\Pi^{\text{inf}} > \Pi^0$, and that there exists at least one project k such that $x_k^* > 0$ and $\Pi_k(\overline{e}) < \Pi_1(\underline{e})$. By proposition 2, there is a time-inconsistency problem: if A recommends such a project k, P has an incentive to break his promise by imposing project 1. To avoid unnecessary complications, the case in which $n = 3$, $k = 2$, and $(x_1^*, x_2^*, x_3^*) = (1, 1, 0)$ (the example in section 4.3), will be used as a case in point.

Suppose there is a third party, called S. The central question is whether the optimal mechanism when commitment is possible (as derived in the previous section) can be implemented if S and P can write a contract on profit-sharing. The contract with S should give the principal incentives to stick to the ex ante optimal mechanism after any proposal by the agent.

The organization's profits are assumed to be contractable. S is risk-neutral, and has a utility reservation level 0. He is not able to verify which project is implemented (e.g. he cannot observe or verify implementation), so that the choice of a project is noncontractable.

S's payoffs of the contract are denoted by $D(\Pi)$ for any possible profit level $\Pi \in V \equiv \{\Pi_i(e)\}_{e=\overline{e},\underline{e}}^{i=1,\ldots,n}$. S transfers upfront an amount

$p \geq 0$ to P; a contract consists of a profit-sharing rule and a fixed transfer.[15] P and S are protected by limited liability, so we have

$$0 \leq D(\Pi) \leq \Pi + p, \quad \forall\, \Pi \in V. \tag{6}$$

The contract signed by P and S can be interpreted as a security or financial contract. In such a setting, S is an investor who purchases a profit-sharing contract at price p (for instance, a share is issued at price p and future dividend levels $D(\Pi)$ are predetermined). Alternatively, S is P's superior (the firm's CEO); P's salary consists of a fixed part or a fixed budget p, and a bonus or punishment $\Pi - D(\Pi)$.

A's project recommendation is private information for P; think of a situation in which S and people on the workfloor do not communicate with each other. Consequently, there is only communication between A and P, and between P and S. In the financial-contract setting, it is natural to assume that investors only have contact with top management. A possible explanation is that the costs for workers and investors to get in touch with one another are too high (see also footnote 20). In the incentive-scheme setting, the organization's CEO may simply have no time to talk with people on the workfloor because of work overload.

Since P cares about net profits, the following incentive-compatibility constraint must be satisfied in order to align his ex ante and ex post incentives:

$$\Pi_2(\overline{e}) - D(\Pi_2(\overline{e})) \geq \Pi_1(\underline{e}) - D(\Pi_1(\underline{e})). \tag{7}$$

Intuitively, if P could commit to burn profits, he could reverse the inequality $\Pi_1(\underline{e}) > \Pi_2(\overline{e})$ by burning at least $\Pi_1(\underline{e}) - \Pi_2(\overline{e})$ if profits $\Pi_1(\underline{e})$ are realized. Signing ex ante a contract on profit-sharing, such that (7) holds, has the same effect.

The contract with S will be required to be renegotiation-proof. When A has recommended a project to P, S makes P a take-or-leave-it

[15] For instance, p is put on a bank account without access until profits are realized. I assume that P has no resources to put into escrow.

offer (the renegotiation stage).[16] Thus S has full bargaining power at this stage, but P can always insist on sticking to the initial, binding contract.

The contract will be called renegotiation-proof if and only it is interim efficient. A contract's payoffs are interim efficient (relative to prior beliefs) if (i) they are incentive compatible, and (ii) there exists no other incentive compatible allocation that Pareto dominates it, and yields S at least as much expected utility (see Maskin and Tirole (1992)).

S's renegotiation offer consists of a menu of new contract payoffs

$$\{d_i(\Pi)\}_{\Pi \in V} \ , \ i = 1, \ldots, n,$$

intended to replace the menu of payoffs $\{D(\Pi)\}$, where i denotes P's announcement of A's recommendation. By the Revelation Principle, restricting S's offer to a direct-revelation mechanism is without loss of generality.[17]

We have the following timing:

$t = 0$: P offers S a contract, observed by A.[18] Nature selects A's private benefits. P communicates $(x_1^*, \ldots, x_n^*)$ to A.

$t = 1$: A decides whether to learn his private benefits.

$t = 2$: A recommends a project to P.

$t = 3$: S proposes P to renegotiate.

$t = 4$: P accepts or rejects S's offer, and executes the corresponding mechanism. A picks an effort level to implement the selected

[16] Accordingly, signaling problems and multiplicity of equilibria are avoided because S's proposal does not reveal information. If P would make S an offer, S would still not be able to observe A's recommendation; this asymmetry of information is crucial for renegotiation-proofness.

[17] See for instance Myerson (1979).

[18] I assume that P has the bargaining power at this stage, because P attracts a third party to solve his credibility problem.

project. Profits are realized and the contract between P and S is executed.

The following lemma identifies the set of renegotiation-proof allocations.

Lemma 2 *The contract between P and S is renegotiation-proof if and only if*

$$D(\Pi_1(\underline{e})) - D(\Pi_2(\overline{e})) \geq \frac{\alpha_2 + \alpha_3}{\alpha_3} \left(\Pi_1(\underline{e}) - \Pi_2(\overline{e})\right). \tag{8}$$

Proof: I will say that the principal has type k if project k was recommended by the agent. The only relevant incentive-compatilibity constraint for the initial contract's payoffs is[19]

$$\Pi_2(\overline{e}) - D(\Pi_2(\overline{e})) \geq \Pi_1(\underline{e}) - D(\Pi_1(\underline{e})). \tag{9}$$

Since there is no allocative gain ex post and no incentive problem if the agent recommends project 1, any proposal by S satisfies $d_1(\Pi_1(\overline{e})) = D(\Pi_1(\overline{e}))$. Moreover, the proposal is incentive compatible if and only if

$$d \equiv d_2(\Pi_1(\underline{e})) = d_3(\Pi_1(\underline{e})). \tag{10}$$

To see this, suppose that (10) does not hold. It is immediate that type $j = \arg\max_{j=2,3} d_j(\Pi_1(\underline{e}))$ would mimic the other type.

It must be that (9) holds with strict inequality. If this were not the case, then S could propose $d = D(\Pi_2(\overline{e})) + \Pi_1(\underline{e}) - \Pi_2(\overline{e})$ and gain in expectation $\alpha_2(\Pi_1(\underline{e}) - \Pi_2(\overline{e}))$. Since $\Pi_1(\underline{e}) - d = \Pi_2(\overline{e}) - D(\Pi_2(\overline{e}))$, the offer would be accepted by P.

Suppose that type 2 accepts S's offer, that is, $\Pi_1(\underline{e}) - d \geq \Pi_2(\overline{e}) - D(\Pi_2(\overline{e}))$. Since (9) holds with strict inequality, type 3 also accepts. So necessarily, by proposing to renegotiate, S runs the risk that he is dealing with type 3 instead of type 2. There does not exist an incentive-compatible allocation such that S is strictly better off in

[19]Other incentive-compatibility constraints can trivially be satisfied; see the proof of proposition 3.

expectation compared to the initial allocation if and only if for all $d \leq D(\Pi_2(\bar{e}))+\Pi_1(\underline{e})-\Pi_2(\bar{e})$, we have that $\alpha_1 D(\Pi_1(\bar{e}))+\alpha_2 D(\Pi_2(\bar{e}))+\alpha_3 D(\Pi_1(\underline{e})) \geq \alpha_1 d_1(\Pi_1(\bar{e}))+\alpha_2 d+\alpha_3 d$. The latter requirement is equivalent to (8). □

The idea of the proof of lemma 2 is to show the following. Suppose S proposes to renegotiate. If P accepts S's offer when A has recommended project 2, which is the only case in which there are mutual gains from renegotiation for P and S, then necessarily P also accepts S's offer when A has recommended project 3. The reason is that S cannot make an offer such that P accepts only if project 2 was recommended.[20] This means that renegotiating is risky for S, in the sense that the fact that P accepts his offer is not informative about whether the "size of the pie" can be increased. Renegotation-proofness amounts to designing the initial contract such that the expected loss of renegotiation for S outweighs the expected gain; S is not willing to accept the gamble.

One can interpret (8) directly by rewriting it as

$$\alpha_3[T(\Pi_2(\bar{e}))-T(\Pi_1(\underline{e}))] \geq \alpha_2[\Pi_1(\underline{e})-\Pi_2(\bar{e})], \tag{11}$$

where $T(\Pi) \equiv \Pi - D(\Pi)$ for all $\Pi \in V$, that is, $T(\cdot)$ denotes profits after paying S. Inequality (11) says that the "expected bribe" to be offered to the principal by S (in order to make him accept the renegotiation offer) exceeds the expected gains that can be divided after the agent's proposal to implement project 2 is not followed up.

[20] Direct communication between A and S would not help the latter. If A could commit himself not to talk with S, he would certainly do so, because renegotiation is bad for A. However, suppose A cannot commit, and S tries to verify P's announcement by asking A about his preferred project. The only way for S to make A reveal his preferences is to promise to implement A's preferred project with positive probability (instead of adopting mechanism $(1,0,0)$). But then, once A has revealed, S no longer has an incentive to carry out such a randomization. Indeed, assuming that S is able to commit himself to carry out suboptimal promises, and *not* able to commit not to renegotiate, would at least be very questionable.

Observation of inequality (8) sheds some light on the role of the prior distribution of A's private benefits. The lower bound for $D(\Pi_1(\underline{e})) - D(\Pi_2(\overline{e}))$, as follows from renegotiation-proofness, is increasing in α_2. Thus the interim-efficiency constraint becomes more stringent if the probability that there are gains from renegotiating increases. Additionally, the interim-efficiency constraint becomes less stringent if α_3 increases, that is, the expected cost of renegotiation becomes larger.

Now the problem of optimal contract design can be formulated. In the following program, which is P's problem at time $t = 0$, the last three constraints are incentive-compatibility constraints. Notice that (8) implies that if A proposes project 2, P has no incentive to impose project 1. Therefore, incentive-compatibility constraint (7) is automatically satisfied.

$$\begin{array}{ll}\max\limits_{p;\, D(\Pi),\, \forall\, \Pi\in V} & p + \sum\limits_{k=1}^{2} \alpha_k[\Pi_k(\overline{e}) - D(\Pi_k(\overline{e}))] + \alpha_3[\Pi_1(\underline{e}) - D(\Pi_1(\underline{e}))] \\ \text{s.t.} & \alpha_1 D(\Pi_1(\overline{e})) + \alpha_2 D(\Pi_2(\overline{e})) + \alpha_3 D(\Pi_1(\underline{e})) \geq p, \\ & D(\Pi_1(\underline{e})) - D(\Pi_2(\overline{e})) \geq \frac{\alpha_2+\alpha_3}{\alpha_3}\left(\Pi_1(\underline{e}) - \Pi_2(\overline{e})\right), \\ & 0 \leq D(\Pi) \leq \Pi + p, \quad \forall\, \Pi \in V, \\ & p \geq 0, \\ & \Pi_1(\overline{e}) - D(\Pi_1(\overline{e})) \geq \Pi - D(\Pi),\ \Pi = \Pi_2(\underline{e}), \Pi_3(\underline{e}), \\ & \Pi_2(\overline{e}) - D(\Pi_2(\overline{e})) \geq \Pi_3(\underline{e}) - D(\Pi_3(\underline{e})), \\ & \Pi_1(\underline{e}) - D(\Pi_1(\underline{e})) \geq \Pi - D(\Pi),\ \Pi = \Pi_2(\underline{e}), \Pi_3(\overline{e}).\end{array}$$

Does there exist a solution to this problem such that S's participation constraint (the first constraint in the program) is binding? Since any returns for S come from realized profits, P's expected profits are equal to $\Pi^{\inf}$ if and only if S's expected net returns are zero.

Proposition 3 *There exists a renegotiation-proof contract such that $(x_1^*, x_2^*, x_3^*) = (1, 1, 0)$ is implemented, and P's expected payoffs are equal to $\Pi^{\inf}$.*

Proof: Let $D^*(\Pi_1(\overline{e})) = \Pi_1(\overline{e})$, $D^*(\Pi_2(\overline{e})) = 0$, and $D^*(\Pi_1(\underline{e})) = ((\alpha_2 + \alpha_3)/\alpha_3)[\Pi_1(\underline{e}) - \Pi_2(\overline{e})]$. Choose p^* such that S's participation constraint is binding, i.e., $p^* = \alpha_1\Pi_1(\overline{e}) + (\alpha_2+\alpha_3)(\Pi_1(\underline{e}) - \Pi_2(\overline{e}))$. It is straightforward to check that the renegotiation-proofness constraint as given in lemma 2, and the other constraints of the program, are satisfied. P's profits equal $\alpha_1\Pi_1(\overline{e}) + \alpha_2\Pi_2(\overline{e}) + \alpha_3\Pi_1(\underline{e}) = \Pi^{\text{inf}}$. Finally, $D^*(\Pi) = \Pi + p^*$ for $\Pi \in \{\Pi_2(\underline{e}), \Pi_3(\overline{e}), \Pi_3(\underline{e})\}$ satisfies the limited liability constraints and also the remaining incentive compatibility constraints. □

By proposition 3, P can credibly commit himself to the optimal mechanism that induces A to get informed. A renegotiation-proof contract with a third party convinces the agent that he can trust his superior's promise. Moreover, since the expected return stream of the contract is equal to its price, the principal is not worse off compared to the case in which commitment was assumed to be possible, that is, his credibility problem can be solved costlessly.

In inequality (11) one can observe that the principal's net profit function $T(\Pi)$, is non-monotonic. Therefore, one has to assume that the principal has no possibility to "throw away" profits $\Pi_1(\underline{e}) - \Pi_2(\overline{e})$. A justification is that wasting money may be easily detected and punished. However, when profit-wasting is difficult to discern, the non-monotonicity of $T(\Pi)$ may be less appealing. In a perhaps more realistic setting, one can imagine that the principal cares about the agent's job satisfaction (the "smile on the agent's face"). Congruence may then be achieved by a low-powered incentive scheme, such as $T(\Pi) = c$ for all Π. Accordingly, low-powered incentives may be preferred over high-powered incentives in order to align incentives in firms.

4.5 Conclusion

In this chapter I investigate a principal-agent relationship in which the principal gives the agent an incentive to exert effort by considering the latter's private benefits (e.g. job satisfaction). The principal can do so by giving the agent responsibility to select a project among a predetermined number of projects. If the agent has enough discretion, he finds it worthwile to learn his private benefits of the possible projects, and recommend his preferred one. Delegation of responsibility may benefit the principal because the agent will work hard if he is allowed to implement his preferred project.

The principal can solve commitment problems, if any, to follow up the agent's recommendation by attracting a third party, such as an outside investor. Profit-sharing with this party allows the principal, who cares about net profits, to align his incentives before and after the agent's project proposal. The contract can be designed such that its price is equal to the expected return stream, so that commitment problems can be costlessly solved.

The principal-agent model presented in this chapter is quite simple, and can be used as a building block for models to investigate various issues. For instance, in De Bijl (1995) the model is applied to study the strategic nature of organizational structure in an oligopolistic market.

Appendix

This appendix developes intuition for the assumption that the agent may hardly respond to pecuniary incentives. For the sake of argument, suppose there is only one possible project (say project 1), and the agent derives utility w if he receives a wage $w \geq 0$. The cost of getting informed is so high that the agent has no incentive to learn his private benefits.

With a salary equal to his reservation wage, the agent's optimal effort level is e_1^0, resulting in private benefits u_1^0 and profits $\Pi_1(e_1^0)$ (for notation see section 2). If profit or effort level is contractable, the agent can be induced to exert effort $e > e_1^0$ by compensating him with a payment scheme

$$w(\Pi) = \begin{cases} u_1^0 - [\alpha_1 U(\bar{b}, e) + (1-\alpha_1) U(\underline{b}, e)], & \text{if } \Pi = \Pi_1(e), \\ 0, & \text{otherwise.} \end{cases}$$

Therefore, the principal's problem is to choose an effort level e for the agent that maximizes

$$\Pi_1(e) - [u_1^0 - (\alpha_1 U(\bar{b}, e) + (1-\alpha_1) U(\underline{b}, e))].$$

Assuming an interior solution, the effort level that is optimal from the principal's point of view, say $\hat{e}$, satisfies the first-order condition

$$\frac{\partial \Pi_1(\hat{e})}{\partial e} = -\alpha_1 \frac{\partial U(\bar{b}, \hat{e})}{\partial e} - (1-\alpha_1) \frac{\partial U(\underline{b}, \hat{e})}{\partial e}, \tag{12}$$

and can be implemented with a salary $w(\Pi) = u_1^0 - \alpha_1 U(\bar{b}, \hat{e}) - (1 - \alpha_1) U(\underline{b}, \hat{e})$ if $\Pi = \Pi_1(\hat{e})$ and $w(\Pi) = 0$ otherwise.

Suppose that the principal pays a salary equal to the agent's reservation wage. If α_1 is small, the agent's effort level will be low, that is, e_1^0 will be relatively close to $\underline{e}$. Moreover, if $\Pi_1(e)$ is relatively flat around e_1^0, then the principal can offer the agent only limited compensation for exerting more effort than e_1^0. To see this, observe the first-order condition (12). If $\partial \Pi_1(\hat{e})/\partial e$ tends to 0, we obtain the first-order condition that determines the agent's optimal effort level when he cares only about his private benefits, e_1^0. Thus, giving the agent a salary on top of his reservation wage hardly increases profits at the optimum. Moreover, $\hat{e}$ will only slightly exceed e_1^0.

Now suppose that private benefits are very important to the agent, so that a high private-benefits project induces relatively high effort compared to e_1^0, $\underline{e}$ and $\hat{e}$. In particular, if the agent would know that $b_1 = \overline{b}$, then resulting profits would satisfy

$$\Pi_1(\overline{e}) > \Pi_1(\hat{e}) - w(\Pi_1(\hat{e})).$$

Typically, there may exist a range of projects $1, \ldots, m$ such that $\Pi_i(\overline{e}) > \Pi_1(e^*) - w(\Pi_1(\hat{e}))$, for all $i = 1, \ldots, m$, and inducing a higher effort level than $\overline{e}$ by a wage scheme is hindered by limited means (the profit function is even flatter around $\overline{e}$). Accordingly, appealing to the agent's sense of job satisfaction is much more effective than using a monetary incentive scheme.

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Chapter 5

Strategic Delegation of Responsibility in Competing Firms

5.1 Introduction

Top managers of firms do not only make "strategic" decisions, for instance on product choice and price setting, but also decide on organizational issues like delegating responsibility to subordinates. Think, for instance, of a product manager who is responsible for his firm's market strategy, and has to decide which product variety to sell in some market segment. A layer below him in the hierarchy, there is a middle manager, such as the head of the development and production department.

In this chapter, I study the strategic impact of organizational structure, or more specific, of giving the middle manager a say in the choice of a product variety that his department has to develop and produce.[1]

[1] *The Economist* (1995) discusses empirical support for the claim that firms "[...] which give middle managers a say in forming strategy perform better" and provides examples of delegation of responsibility. For instance, "Honda developed its Civic car by giving a group of young middle managers broad guidelines (make it youth-friendly and fuel-efficient) and letting them get on with the job." Also, "Motorola's middle managers have had a say in designing its Iridium satellite project"

A duopoly model of competing hierarchies demonstrates some possible linkages between internal organization and market strategy.

Consider, as an example of the model, an oligopolistic market for a soft drink, say cola, in which consumers have different preferences for different varieties (such as regular cola, cherry cola, diet cola, and caffeine-free cola). For each variety, consumers are willing to pay more for higher quality. Suppose price competition is fierce: for given qualities, a firm gains more if it positions its brand in a market niche (by differentiating its product), than if it sells a drink aimed at an "average" taste.[2]

Each firm consists of a product manager and his subordinate (or middle manager), who represents the development and production department.[3] The product manager has to choose which cola type to sell, and at which price. The subordinate performs development and production activities; quality is determined by his effort level. Whereas a product manager cares about sales or profits, his subordinate is motivated by private benefits. For instance, because of career concerns he finds the acquisition of professional experience important, or alternatively, he is challenged by technical innovativeness of products. Developing and producing a certain type of cola requires specific technical knowledge (e.g. about chemicals and production processes), so that his enthusiasm for different types of colas will vary.

A product manager does not know how his subordinate's preferences. The subordinate, however, has to invest costly time and effort to find out his potential personal gains. A manager can either impose which variety has to be produced (e.g. impose diet cola), or give his

(p. 70). Obviously, there may be a combination of reasons (e.g. incentives, information, flexibility, work overload) for decentralizing strategic decisions.

[2]Casual empirical evidence suggests that product differentiation is an important source of profits in soft drink markets. Coca-Cola, for instance, has recently introduced, among other varieties, ginseng-based and milk-based drinks in Japan, and sugar-free colorless cola in America (*The Economist* (1993)).

[3]Obviously, there may also be conflicts of interest between the middle manager and the engineers of his department, raising a host of additional interesting issues.

subordinate a say in the choice of variety (e.g. let him choose between diet cola and caffeine-free cola, but not regular and cherry cola). If the subordinate has sufficient discretion, he will want to acquire information about the possible drink types, so that he can recommend his preferred variety. If he is allowed to develop and produce his preferred variety, he will exert maximal effort, and high quality will result.

For expositional purposes, I assume that the possible product locations vary (on an interval) from the market niche that the manager would like to aim at, to a location representing consumers' average taste. This assumption, will create a tension between the superior's wishes (who experiences that price competition is fierce) and his subordinate's wishes (who does not directly experience market competition).

In the model, a product manager faces the following tradeoff. If he gives his subordinate more discretion, it becomes more likely that he will get informed in order to make a proposal which, if accepted, will lead to a high quality drink (a premium brand). The subordinate's proposal, however, may imply little differentiation from other cola varieties, and therefore result in fierce price competition. Less discretion enables the manager better to position a drink in a market niche, so that local monopoly profits can be enjoyed. The subordinate's incentives to take initiative and exert effort, however, decrease, so that expected quality will be lower.

In the model, the possible cola varieties correspond to locations on an interval representing consumers' different tastes. It is therefore convenient to make a comparison with the Hotelling model. In the standard Hotelling model with quadratic transportation costs, the demand effect (firms want to be "where the demand is"), outweighs the strategic effect (firms want to be local monopolists) (see D'Aspremont et al. (1979)). Consequently, firms differentiate their products as much as possible in order to soften price competition. In my model, an *incentive effect* also counteracts the strategic effect. If this effect becomes stronger, managers will delegate more responsibility to their subordinates, and products will be less differentiated. In particular, a higher impact of quality on profits favors more discretion in equilibrium.

Delegation decisions relate to organizational structure and market strategy. Thus, studying the strategic nature of delegation yields several implications in the field of management strategy.[4] The optimal level of discretion, as a function of the discretion level in the rival firm, may be increasing ("strategic complements") as well as decreasing ("strategic substitutes"), depending on the revenue functions. Delegation of responsibility makes a firm "tough" in the sense that it reduces the profits of the rival firm; more discretion results in a higher probability of high quality, and a less horizontally differentiated product. Moreover, from the viewpoint of an incumbent facing a potential entrant, an optimal entry accomodation strategy is to give the subordinate little discretion (in the terminology of the taxonomy of management strategies of Fudenberg and Tirole (1984): adopt a "puppy dog" strategy). The reason is that delegating less responsibility results in a more differentiated product, which softens price competition if entry occurs. By the same intuition, the optimal entry deterrence strategy is to empower the agent (to become a "top dog").

An interesting observation is that in the model, an authoritarian leadership style (the subordinate gets little discretion) corresponds to a soft stance on the product market, and "hands-off" management corresponds to an aggressive market stance. Without claiming generality, this result points out that leadership styles may be perceived quite differently inside and outside a firm.

In typical models of industrial organization, firms are viewed as "black boxes." Although this approach has led to important insights, it has major shortcomings. As Spulber (1992) argues: "For economic models to have practical value to managers, they need to address the choice of both *competitive actions* and *organizational design*" (p. 536,

[4]Management strategy studies how a manager optimally designs the firm's organization and market strategy, taking any public constraints into account (see Spulber (1994)).

emphasis in original). By combining organization theory and industrial organization, this chapter makes a preliminary attempt at shortening the gap between economic theory and management strategy.

The main literature on competition and organizational incentives studies situations in which managers play a market game on behalf of owners (see for instance Vickers (1985), Fershtman and Judd (1987), Sklivas (1987), and Katz (1991)). The question in that literature is whether contracts between owners and managers can serve as precommitments. Having an agent play the market game may, for instance, result in lower quantities or higher prices. The fundamental difference with that literatures is that I abstract from agency problems between owners and managers, and instead look at delegation *inside* firms. Delegation of responsibility serves an organizational purpose – namely, it motivates a subordinate to take initiative and exert effort (although commitment may play a role). Also, an important difference is that in my model, the *principals* compete on the market, by selling goods produced by their agents.

In Horn et al. (1994), contracts between owners and managers give a manager incentives to reduce the cost of production. A common feature of their paper and mine is that organizational design takes place before market decisions are taken. Their analysis suggests a negative relation between incentives to reduce costs and the competitiveness of product market interaction. In my model, which focuses on quite different issues, stronger incentives (more responsibility for a subordinate) result in more severe price competition.

The organizational model is based on De Bijl (1995). In that paper, which in turn was inspired by Aghion and Tirole (1994), I investigate a principal-agent relationship in which the principal appeals to the agent's private benefits from exerting effort, such as job satisfaction, by giving him a say in the selection of the project the agent has to implement. Although the principal has the formal authority to select a project, it is in his interest to pick one that generates interest from the agent. Thus, although the superior has formal authority (the decision right), the subordinate may to some extent have real authority (see also Tirole (1994)).

The model is presented in the next section. The analysis and a discussion of its implications is in section 5.3. Finally, section 5.4 concludes.

5.2 The Model

The model consists of three building blocks: a Hotelling-type product market, the organization of a firm, and competition between vertical structures. These will be taken up in turn.

5.2.1 Product Market Competition

There are two firms, called 1 and 2. Firm 1 can choose a horizontal product specification (or product location) $x_1 \in [-1, 0]$, and firm 2 a product specification $x_2 \in [0, 1]$.[5] The vertical product quality of firm i is denoted by r_i.

Consumers are uniformly distributed along the interval $[-1, 1]$. The willingness to pay of a consumer "located" at z for firm i's product is decreasing in the distance between z and x_i, and increasing in r_i. A consumer has an inelastic demand for one unit; she purchases the good that gives her the highest net surplus.

Once product characteristics are fixed (see below), the firms compete on the product market by simultaneously setting prices. Marginal costs are equal and normalized to zero. Before the price competition stage, the firms observe each others' product characteristics. To keep the analysis tractable, price competition is not modeled explicitly. I will assume that given product locations x_1 and x_2, and qualities r_1

[5]This assumption rules out coordination problems among firms, in order to focus the analysis on more crucial issues.

and r_2, there exists a unique equilibrium in the price subgame. Also, qualities are sufficiently high so that the market is always covered.

Given the unique equilibrium outcome in the price subgame, firm i's revenue (or profit) function is denoted by $R_i(x_1, x_2; r_1, r_2) \geq 0$, which is twice continuously differentiable in x_1 and x_2 ($i = 1, 2$).

Assumption 1 *(Revenue functions)*
(i) $R_i(x_1, x_2; r_1, r_2)$ is strictly increasing in r_i, and strictly decreasing in r_j, for all x_1, x_2, $i = 1, 2$.
(ii) $R_i(x_1, x_2; r_1, r_2)$ is strictly decreasing in x_1, and strictly increasing in x_2, for all r_1, r_2, $i = 1, 2$.

The interpretation of assumption 1 is direct. A firm's profit level is increasing in its own vertical product quality, and decreasing in its rival's quality. Furthermore, given quality levels, the firms would like to differentiate as much as possible to soften price competition. So implicitly, on the interval $[-1, 1]$ the strategic effect (firms want to be local monopolists) dominates the demand effect (firms want to be "where the demand is").[6] Thus, the model applies to markets in which it is profitable for firms to position brands in market niches. Moreover, the assumption will allow for easy comparison with the maximum differentiation result of the Hotelling model with quadratic transportation costs.

5.2.2 Organization of a Firm

The way a firm is organized is adapted from De Bijl (1995). Firm i consists of a principal P_i (the manager) and an agent A_i (the manager's subordinate), $i = 1, 2$. The role of a principal in a firm is either

[6]Cf. the Hotelling location model with quadratic transportation costs, some finite reservation value for consumers, and possibly different vertical product qualities. The willingness to pay of a consumer located at z for good i in that model is $r_i - p_i - d(z - x_i)^2$, where p_i is the price of the good, and d a measure of the transportation cost. For $r_1 = r_2$, product locations in equilibrium are $x_1^* = -1$ and $x_2^* = 1$ (see D'Aspremont et al. (1979)).

to impose a horizontal product specification or to delegate the product location to his agent. Given product location, the subordinate takes care of development and production, and vertical product quality is determined by his effort level. Once location and quality are determined, the manager chooses a price in order to maximize expected profits.

An agent is motivated to exert effort by private benefits, which are related to horizontal product characteristics. Private benefits may include job satisfaction, a sense of achievement and accomplishment, perks on the job, the acquisition of professional experience, career concerns, and so on. For simplicity, the agent does not respond to pecuniary incentives. For instance, the agent is infinitely risk averse with respect to income. Accordingly, each agent receives a constant salary equal to his reservation wage, which is normalized to zero.[7]

A_1's private benefits are determined by Nature as follows. Exactly one point in $[-1, 0]$ yields the agent benefits $\overline{b}$; all the other product locations yield $\underline{b} < \overline{b}$ (where $\underline{b} > 0$). The location of the high private-benefit point is uniformly distributed on $[-1, 0]$.[8] The private benefits of A_2 are determined in a similar fashion on the interval $[0, 1]$, and are independent of A_1's private benefits. Let

$$\Delta \equiv \overline{b} - \underline{b}.$$

If A_i is not allowed to produce the high private-benefits good then he will exert low effort, which results in low vertical quality $r_i = \ell > 0$. Conversely, producing a good which yield high private benefits results in high product quality $r_i = h > \ell$.[9] Note that by abstracting from

[7]In De Bijl (1995) I show that abstracting from payments does not harm generality if an agent is relatively more responsive to private benefits than to money.

[8]The discontinuity in the distribution simplifies the exposition; it is not crucial for the insights.

[9]One can explicitly model an agent's behavior. Suppose an agent has a utility function $U(b, e)$, where b denote private benefits and e his effort level. Assume $U(b, e)$ is increasing in b for all e, strictly concave in e for all b, and satisfies $\partial^2 U(b, e)/(\partial b \partial e) > 0$. It follows that the agent's optimal effort level $e^*(b)$ is increasing in b.

pecuniary incentives, punishments based on low effort are ruled out.

The realization of A_i's private benefits can only be observed by A_i, but he has to incur a private cost $F \geq 0$ (for instance, time and effort) to do so. The principal cannot verify whether his agent gets informed.

P_1's delegation decision is expressed by a function $p_1 : [-1, 0] \to [0, 1]$, such that if A_1 recommends product location x_1, he is allowed to produce the good located at x_1 with probability $p_1(x_1)$, but has to produce the good at -1 with probability $1 - p_1(x_1)$. Similarly, P_2's delegation scheme is described by a function $p_2 : [0, 1] \to [0, 1]$ (A_2 has to produce good 1 with probability $1 - p_2(x_2)$ given proposal x_2). So

$$p_i(x_i) = \Pr(A_i \text{ is allowed to produce good } x_i \mid A_i \text{ proposed } x_i).$$

Whether an agent will learn his private benefits depends on the discretion he has. A_1 gets informed if and only if[10]

$$\int_{-1}^{0} [p_1(x_1)\overline{b} + (1 - p_1(x_1))\underline{b}]\mathrm{d}x_1 - F \;\geq\; \underline{b},$$

or equivalently,

$$\int_{-1}^{0} p_1(x_1)\mathrm{d}x_1 \geq \frac{F}{\Delta}. \tag{1}$$

One can write down a similar inequality for A_2.

To make the analysis interesting, the following assumption is made:

Assumption 2 $F < \Delta$, *implying that if an agent has complete responsibility concerning product location ($p_i(x_i) = 1$ for all x_i) then he will get informed.*

An uninformed agent is indifferent between the possible locations. For simplicity, he will then propose the principal's preferred location.

I assume that a principal can commit himself to a delegation scheme; the focus is on delegation as a means to motivate a subordinate.[11] A

[10] To be precise, $\overline{b}$ and $\underline{b}$ represent the private benefits obtained by the agent given his optimal effort level; e.g., using notation introduced in footnote 9, $\overline{b}$ represents $U(\overline{b}, e^*(\overline{b}))$.

[11] It will be shown that $p_i(x_i) \in \{0, 1\}$ for all x_i, so that there is no need to assume that principals can commit themselves to carry out randomizations.

justification is that a manager cares about his reputation to keep a promise. Since selling a high-quality good located at x_i may yield higher profits than selling a more differentiated low-quality good for all x_i that satisfy $p_i(x_i) > 0$, delegation schemes may be optimal ex post; the assumption is not crucial. This is typically the case if high quality has a relatively large impact on revenues, compared to differentiation.

5.2.3 Competing Organizational Structures

The principals compete with each other; they face each other on the product market. There is no interaction between the agents, and they cannot communicate with each other. The course of events is as follows:

$t = 0$: Nature selects the agents' private benefits, unobserved at this stage.

$t = 1$: The principals simultaneously choose delegation schemes, unobservable outside each firm. Each principal communicates the delegation scheme to his agent, who then decides whether to learn his private benefits. The latter decision is private information for an agent. The agents then simultaneously recommend product locations to their principals. Product locations are simultaneously selected according to the delegation schemes. An agent's proposal and the selected location are unobservable outside each firm at this stage.

$t = 2$: Each agent picks a production effort level, resulting in certain vertical product qualities.

$t = 3$: Product locations and qualities are observed. The principals simultaneously set prices and the goods are sold on the market.

It is important to notice that once production has taken place, delegation schemes no longer matter; only product locations and qualities influence the prices that are charged in the market.

In the analysis that follows, subgame perfect equilibria in pure strategies are derived. Since the price stage is not modeled explicitly, essentially the principals compete by simultaneously selecting delegation schemes. The analysis focuses on symmetric equilibria.

5.3 Analysis

5.3.1 Equilibria

The first proposition allows us to represent delegation schemes by well-defined "discretion levels." In particular, in any equilibrium $p_i^*(x_i) = 1$ for all x_i in some interval containing firm i's maximally differentiated product location, and $p_i^*(x_i) = 0$ otherwise.[12] A discretion level for firm i's agent, denoted by X_i, is accordingly defined as the length of the interval on which $p_i(x_i) = 1$. A higher level of X_i corresponds to more responsibility for agent A_i. In particular, if $X_i = 0$ then firm i's manager imposes his agent to produce the maximally differentiated product. If $X_i = 1$, agent A_i has full responsibility.

Proposition 1 *In any equilibrium, there exist discretion levels $X_i^* \in [0,1]$, $i = 1,2$, such that A_1's recommendation x_1 is followed up if and only if $x_1 \leq -1 + X_1^*$, and A_2's recommendation x_2 is followed up if and only if $x_2 \geq 1 - X_2^*$.*

Proof: See the appendix.

Intuitively, given the level of responsibility the rival firm's agent has, each principal faces the following tradeoff. Giving his agent little discretion results in a lack of initiative: the agent has no incentive to learn his private benefits and make a recommendation. The maximally differentiated product will be produced, but quality will be low.

[12] A similar result is obtained in De Bijl (1995), with a discrete number of projects and in the absence of a rival firm.

Much discretion results in initiative: the agent will get informed and recommend his preferred product location. The product will be less differentiated, but quality will be high if the proposal is followed up.

Using (1), a direct consequence of proposition 1 is that A_i gets informed if and only if he has enough discretion.

Corollary 1 *Agent A_i gets informed if and only if $X_i \geq \frac{F}{\Delta}$.*

Some additional notation is introduced. Let $\rho_i : [0,1] \times [0,1] \to \mathbb{R}$ denote P_i's expected revenue as a function of (X_1, X_2), given that both agents get informed, $i = 1, 2$. Accordingly,

$$\begin{aligned}\rho_i(X_1, X_2) &= \int_{-1}^{-1+X_1} \left(\int_{1-X_2}^{1} R_i(x_1, x_2; h, h)\mathrm{d}x_2 + (1 - X_2) R_i(x_1, 1; h, \ell) \right) \mathrm{d}x_1 \\ &\quad + (1 - X_1) \left(\int_{1-X_2}^{1} R_i(-1, x_2; \ell, h)\mathrm{d}x_2 + (1 - X_2) R_i(-1, 1; \ell, \ell) \right).\end{aligned}$$

Firm i's expected profits, a function $\pi_i : [0,1] \times [0,1] \to \mathbb{R}$, can now be defined as follows.

$$\pi_i(X_1, X_2) = \begin{cases} \rho_i(X_1, X_2) & \text{if } X_1 \geq \frac{F}{\Delta} \text{ and } X_2 \geq \frac{F}{\Delta}, \\ \rho_i(X_1, 0) & \text{if } X_1 \geq \frac{F}{\Delta} \text{ and } X_2 < \frac{F}{\Delta}, \\ \rho_i(0, X_2) & \text{if } X_1 < \frac{F}{\Delta} \text{ and } X_2 \geq \frac{F}{\Delta}, \\ \rho_i(0, 0) & \text{otherwise.} \end{cases}$$

With expected profits written as functions of levels of discretion, we are ready to derive the main results. The following lemma will be invoked repeatedly.

Lemma 1 *(i) $\rho_i(X_1, X_2)$ is strictly decreasing in X_j, for all X_i, $i, j = 1, 2$, $i \neq j$,*
(ii) $\rho_i(X_1, X_2)$ is strictly concave in X_i, for all X_j, $i \neq j$, and
(iii) $\partial\rho_1(0, X_2)/\partial X_1 > 0$, for all X_2; and $\partial\rho_2(X_1, 0)/\partial X_2 > 0$, for all X_1.

Proof: Differentiate $\rho_i(X_1, X_2)$ partially (twice to prove part (ii)) and apply assumption 1. □

If we suppose that agents can costlessly observe their private benefits, so that $\pi_i(X_1, X_2) = \rho_i(X_1, X_2)$, $i = 1, 2$, then lemma 1 has straightforward interpretations. According to part (i), a principal wants the agent of the rival firm to have as little discretion as possible. Notice the similarity with the assumption that a firm wants the rival firm to locate as far away as possible. The effect of little discretion for the rival firm's agent is, however, twofold: first, it softens price competition, and second, it results in a low probability that the rival product will be of high quality. Using terminology of Fudenberg and Tirole (1984), delegation of responsibility makes a firm "tough," in the sense of reducing the rival firm's profits.

A straightforward implication of lemma 1 (iii) is the following:

Corollary 2 *If $F = 0$ then in any equilibrium each principal gives his agent some responsibility, i.e., $X_1^* > 0$ and $X_2^* > 0$.*

The next proposition gives necessary and sufficient conditions for existence of an equilibrium in which both agents have full discretion. Informally, proposition 2 states that both agents have full discretion in an equilibrium when selling a high-quality product is more profitable than selling a maximally differentiated product. Expected product locations are $-\frac{1}{2}$ and $\frac{1}{2}$. Since the agents have complete freedom to pick product location, both products will be of high quality.

Proposition 2 *There exists an equilibrium in which each principal gives his agent complete responsibility, i.e., $X_1^* = X_2^* = 1$, if and only if*

$$\int_0^1 R_1(0, x_2; h, h)\,dx_2 \geq \int_0^1 R_1(-1, x_2; \ell, h)\,dx_2. \tag{2}$$

Proof: By lemma 1 we have $\rho_1(X_1, 1)$ is strictly concave in X_1, and also $\partial\rho_1(X_1, 1)/\partial X_1 \,|_{X_1=0} > 0$. Therefore, $X_1^* = 1$ is a best response to $X_2^* = 1$ if and only if

$$\left.\frac{\partial\pi_1(X_1, 1)}{\partial X_1}\right|_{X_1=1} \geq 0,$$

equivalent to inequality (2). The result follows by symmetry. □

Inequality (2) can be interpreted directly in terms of product characteristics: given that the rival firm's agent has full discretion (which implies high vertical product quality), a principal prefers to sell a high-quality product located at the center (that is, at 0) to a low-quality product that is maximally differentiated.

Proposition 2 demonstrates that in addition to the demand effect, there is an *incentive effect* that opposes the strategic effect. A manager may want to empower his subordinate to select product location because it will result in high product quality. Under condition (2), and also under the conditions for equilibria with intermediate discretion that are given in proposition 4 below, the incentive effect is sufficiently strong so that we do no longer observe the maximal differentiation result of the Hotelling model.

By corollary 2, an equilibrium in which each principal imposes his agent to produce the maximally differentiated product exists only if $F > 0$.

Proposition 3 *Suppose that $F > 0$. There exists an equilibrium in which each principal gives his agent no responsibility, i.e., $X_1^* = X_2^* = 0$, if and only if*

$$\int_{-1}^{\frac{F}{\Delta}-1} R_1(x_1, 1; h, \ell) dx_1 < \tfrac{F}{\Delta}\, R_1(-1, 1; \ell, \ell). \tag{3}$$

Proof: Let $F > 0$. By lemma 1, $\rho_1(X_1, 0)$ is strictly concave in X_1, and $\partial\rho_1(X_1, 0)/\partial X_1 \mid_{X_1=0} > 0$. Therefore, $X_1^* = 0$ is a best response to $X_2^* = 0$ if and only if $\pi_1(\frac{F}{\Delta}, 0) < \pi_1(0, 0)$, equivalent to inequality (3). The result follows by symmetry. □

A necessary condition for (3) is

$$R_1(0, 1; h, \ell) < R_1(-1, 1; \ell, \ell). \tag{4}$$

To see this, notice that by lemma 1, inequality (3) (equivalent to $\rho_1(\frac{F}{\Delta},0) < \rho_1(0,0)$) implies

$$R_1(-1,1;\ell,\ell) = \rho_1(0,0) > \max_{X_1 \in [\frac{F}{\Delta},1]} \rho_1(X_1,0) \geq$$

$$\rho_1(1,0) = \int_{-1}^{0} R_1(x_1,1;h,\ell)\mathrm{d}x_1 > R_1(0,1;h,\ell).$$

Inequality (4) can be interpreted more directly than condition (3). It says that a principal prefers to sell a low-quality, maximally differentiated product to a high-quality, minimally differentiated product, given that the rival firm produces a low-quality product that is maximally differentiated. Thus, high quality does not have a large impact on profits, compared to product differentiation.

As proposition 3 demonstrates, the model is able to generate the well-known maximum differentiation result of the Hotelling model with quadratic transportation costs. This occurs when the incentive effect is relatively weak, so that the strategic effect dominates both the demand effect and the incentive effect.

There may also exist equilibria in which agents have an intermediate level of discretion, enough to motivate them to get informed.

Proposition 4 *There exists an equilibrium in which each principal gives his agent limited responsibility, i.e.,* $X_1^* = X_2^* \in [\frac{F}{\Delta},1)$, *if and only if there exists an* $X_1^* \in [\frac{F}{\Delta},1)$ *such that*

$$\int_{1-X_1^*}^{1} [R_1(-1+X_1^*,x_2;h,h) - R_1(-1,x_2;\ell,h)]dx_2$$

$$\begin{cases} = (1-X_1^*)[R_1(-1,1;\ell,\ell) - R_1(-X_1^*+1,1;h,\ell)] \text{ if } X_1^* \in (\frac{F}{\Delta},1), \\ \leq (1-X_1^*)[R_1(-1,1;\ell,\ell) - R_1(-X_1^*+1,1;h,\ell)] \text{ if } X_1^* = \frac{F}{\Delta}, \end{cases} \tag{5}$$

and $\rho_1(X_1^*,X_2^*) \geq \rho_1(0,X_2^*)$ *if* $X_1^* = \frac{F}{\Delta}$.

Proof: (i) Suppose that $X_2^* \in (\frac{F}{\Delta},1)$. By lemma 1, $\rho_1(X_1,X_2^*)$ is strictly concave in X_1, and $\partial\rho_1(X_1,X_2^*)/\partial X_1 \mid_{X_1=0} > 0$. Therefore,

$X_1^* = X_2^*$ is a best response to X_2^* if and only if

$$\left.\frac{\partial \pi_1(X_1, X_2^*)}{\partial X_1}\right|_{X_1 = X_2^*} = 0,$$

equivalent to the equality in (5). The result follows by symmetry.
(ii) Suppose that $X_1^* = \frac{F}{\Delta}$. By lemma 1, $X_1^* = \frac{F}{\Delta}$ is a best response to $X_2^* = \frac{F}{\Delta}$ if and only if

$$\left.\frac{\partial \rho_1(X_1, \frac{F}{\Delta})}{\partial X_1}\right|_{X_1 = \frac{F}{\Delta}} \leq 0$$

(equivalent to the inequality in (5)) and $\pi_1(\frac{F}{\Delta}, \frac{F}{\Delta}) \geq \pi_1(0, \frac{F}{\Delta})$. The result follows by symmetry. □

Condition (5) in proposition 4 states that X_1^* is a best response to $X_2^* = X_1^*$. For $X_2^* \in (\frac{F}{\Delta}, 1)$, we have a standard first-order condition. For $X_2^* = \frac{F}{\Delta}$, the discontinuity of firm 1's profit function implies that we must require that a marginal increase in A_1's discretion (at $X_1^* = \frac{F}{\Delta}$) does not increase firm 1's expected profits. This explains the inequality in (5).

It is straightforward to derive existence conditions for asymmetric equilibria, but this involves tedious notation without getting additional insights. For simplicity, suppose that $F = \Delta$. Then there exists an equilibrium in which one principal gives his agent responsibility and the other does not, that is, either $X_1^* = 1$ and $X_2^* = 0$ or $X_1^* = 0$ and $X_2^* = 1$, if and only if

$$\rho_1(1, 0) \geq \rho_1(0, 0) \text{ and } \rho_2(1, 1) < \rho_2(1, 0). \tag{6}$$

These inequalities are standard Nash equilibrium conditions. The second condition in (6) can also be written as $\rho_1(1, 1) < \rho_1(0, 1)$. Since $\rho_1(1, 1) < \rho_1(1, 0)$ and $\rho_1(0, 1) < \rho_1(0, 0)$, asymmetric equilibria may indeed exist.

5.3.2 Strategic Complements or Substitutes?

Applying notions developed by Bulow et al. (1985) and Fudenberg and Tirole (1984), I will analyze whether an increase of the level of discretion in a rival firm induces a manager to delegate more or less responsibility to his subordinate. In the former case, reaction functions are upward sloping, and discretion levels are said to be strategic complements. In the latter case, reaction functions are downward sloping, and discretion levels are strategic substitutes.[13]

Given a unique equilibrium outcome of the price subgame, we can focus on competition in delegation schemes, represented by the levels of discretion X_1 and X_2. Firm i's best response (or reaction function) to X_j ($j \neq i$) is defined as

$$X_i^*(X_j) \equiv \arg \max_{X_i \in [0,1]} \pi_i(X_1, X_2).$$

The following example illustrates one of many possible situations.

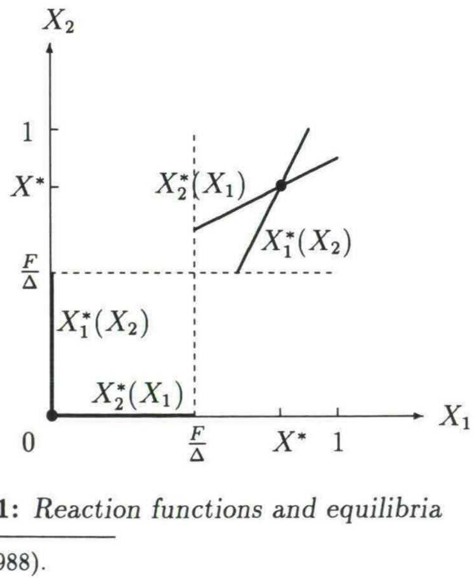

Figure 1: *Reaction functions and equilibria*

[13]See also Tirole (1988).

Example: (see figure 1)
For an intermediate value of F, suppose that inequalities (3) and (5) hold. By propositions 3 and 4, there are two symmetric equilibra, namely $(0,0)$ and (X^*, X^*) for some $X^* \in [\frac{F}{\Delta}, 1)$. For an expositional purpose, reaction functions are assumed to be increasing in the regions where agents acquire information.

Suppose now that $F = 0$, so that we need not worry about discontinuities in the reaction functions. Define for all X_1,

$$\alpha_1(X_1) \equiv R_1(-1 + X_1, 1; h, \ell) - R_1(-1, 1; \ell, \ell),$$

and for all X_1 and X_2,

$$\beta_1(X_1, X_2) \equiv R_1(-1 + X_1, 1 - X_2; h, h) - R_1(-1, 1 - X_2; \ell, h).$$

The value of $\alpha_1(X_1)$ is firm 1's gain from selling a high-quality product located at $-1 + X_1$ compared to selling a maximally differentiated, low-quality product, given that firm 2 produces a low-quality product located at the extreme. The value of $\beta_1(X_1, X_2)$ represents a similar gain given that firm 2 sells a high-quality product located at $1 - X_2$.

Proposition 5 *Suppose $F = 0$.*
(i) If $\alpha_1(X_1) > \beta_1(X_1, X_2)$ for all X_1, X_2, levels of discretion are strategic complements.
(ii) If $\alpha_1(X_1) < \beta_1(X_1, X_2)$ for all X_1, X_2, levels of discretion are strategic substitutes.

Proof: Differentiate the first-order condition $\partial\pi_i(X_i^*(X_j), X_j)/\partial X_i = 0$ with respect to X_j (assuming an interior solution), and apply part (ii) of lemma 1. It follows that the sign of $\mathrm{d}X_i^*(X_j)/\mathrm{d}X_j$ (which determines the slope of reaction function $X_i^*(X_j)$) is equal to the sign of

$$\begin{aligned}\frac{\partial^2\pi_1(X_1, X_2)}{\partial X_1 \partial X_2} &= R_1(-1 + X_1, 1; h, \ell) - R_1(-1 + X_1, 1 - X_2; h, h) + \\ &\qquad R_1(-1, 1 - X_2; \ell, h) - R_1(-1, 1; \ell, \ell). \qquad (7)\end{aligned}$$

By rewriting (7) as $\partial^2\pi_1(X_1, X_2)/(\partial X_1 \partial X_2) = \alpha_1(X_1) - \beta_1(X_1, X_2)$, the result follows. □

The interpretation is direct. Suppose revenues of selling a high-quality product compared to maximally differentiating its product (which would imply low quality) are higher if its rival sells a low-quality product located at the extreme, than if its rival sells a high-quality product (not necessarily located at the extreme). Then P_j's best response to more discretion for agent A_i is to give his agent A_j more discretion as well. There is a similar interpretation of the sufficient condition for strategic substitutes.

5.3.3 Top Dog or Puppy Dog?

Suppose that only one firm, say firm 1, is active in the market, and that firm 2 is a potential entrant. One can distinguish two cases: the incumbent's manager wants to deter entry, or he wants to accomodate entry (for instance because entry deterrence is not profitable). In each case, the incumbent's manager has to formulate an appropriate strategy. In case of accomodation for instance, he will want to choose a strategy that softens post-entry price competition. In what follows, I assume that firm 2's manager decides on entry (and if he enters, on how much responsibility he will delegate) after having observed in which market niche firm 1's product is located, and which quality firm 1 is selling.

The taxonomy of management strategies proposed by Fudenberg and Tirole (1984) is used to characterize empowerment as a strategy to accomodate or deter entry. Consider the level of discretion of an agent as the strategic "investment" variable. A difference with Fudenberg and Tirole's set-up is that in my model, the product characteristics resulting from "investment" is observable, whereas in their analysis, investment itself can be observed. This difference, however, does not matter. The reason is that although delegation schemes are unobservable, each manager can observe the other's product location and quality before competing on the product market. What is essential is that once production has taken place, delegation schemes no longer matter; only the product characteristics are then relevant.

In the product market subgame, prices are strategic complements for given product characteristics.[14] Moreover, by lemma 1 (i), delegation of responsibility makes a firm tough in the sense of reducing the rival firm's profits.

Suppose that, for a fixed level of discretion for A_2, the principal of firm 1 delegates more responsibility to A_1. The total effect, which is P_1's incentive to delegate responsibility, is given by $\partial\pi_1(X_1, X_2)/\partial X_1$. This effect can be decomposed into two effects. First, a direct (or profit maximizing) effect of giving A_1 more responsibility is that for given prices, firm 1's expected market share and product quality, and therefore profits, increase. Second, there is a strategic effect, resulting from firm 2's price reaction. If A_1 gets more discretion, the probability that firm 1's product will be located closer to the center increases. Therefore, in expectations the products will be less differentiated, so that price competition becomes more intense. In particular, it will be expected firm 2 will react by lowering its price, thereby decreasing firm 1's market share and profits.

Given that firm 1 wants to accomodate entry, the fact that delegation makes a firm tough implies that P_1 should "underinvest" in delegation.[15] In the terminology of Fudenberg and Tirole, P_1 should adopt a "puppy dog ploy," that is, it should be nice and small in order to avoid to trigger an aggressive response from firm 2. The optimal entry deterrence strategy for firm 1 is to "overinvest" in delegation, that is, adopt a "top dog" strategy in order to be a tough rival. Such a strategy will reduce profits of an entrant.

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[14]See Tirole (1988), chapter 7, for a discussion.

[15]More precisely, X_1 will be lower than the open-loop solution, which is defined as the optimal value of X_1 if P_2 cannot observe the product characteristics of firm 1's product before setting a price.

5.3.4 Different Perceptions of Management Style

The discussion above points at an interesting link between a manager's stance inside a firm and his posture on the product market. In particular, in the model there are different perceptions of a single leadership style.

Being nice to the rival firm corresponds to adopting a tougher posture vis-à-vis his subordinate, because there is underinvestment in delegation of responsibility. More general, the model demonstrates that motivating the subordinate to take initiative by delegating responsibility corresponds to a more aggressive stance on the product market. Accordingly, a product manager may give his subordinates a lot of freedom ("hands-off" management); not because he is such a nice and friendly person, but because he is a tough competitor. Vice versa, an authoritarian manager (i.e., a manager who gives his subordinate little or no discretion) is a soft rival in the product market. Summarizing: *a tougher posture of a manager inside a firm (i.e., with regard to his subordinate) corresponds to a softer posture on the product market (i.e., with regard to the rival firm), and vice versa.*

Without claiming generality of this dichotomy, the result tells us that it is important to recognize the strategic consequences of different leadership styles. Moreover, statements like "Mr. X is a tough manager" may have little meaning if one does not specify with regard to whom.

5.4 Conclusion

In the model, a product manager makes the realization of high quality more likely by giving his subordinate a say in the variety that has to be developed and produced. Substantial discretion to select a variety motivates him to get informed and make a proposal. In turn, following up the recommendation induces him to exert high effort, because he will work harder on developing and producing goods that yield him higher personal gains. Since high effort results in high product quality, a product manager may find it beneficial to give his agent a say in product location (the incentive effect). The associated cost is that less product differentiation becomes more likely. The incentive effect helps the demand effect ("aim at the average taste") to counteract the strategic effect ("aim at a niche"), so that less product differentiation than in the Hotelling model with quadratic transportation costs can occur.

In the model there is a tension between positioning a brand in a market niche and producing a premium brand. By assuming that the subordinate can propose locations that are even more differentiated than the manager's preferred niche, the maximum differentiation result of the Hotelling model may be enforced.

In reality, there may be a combination of reasons of why top managers delegate responsibility to middle managers - not only incentive issues, but for instance also work overload, flexibility (versus commitment) to adapt to changing market characteristics, or the collection of information about the market. The strategic nature of those and other issues related to organizational structure seems to be a fruitful and important area for further research.

Appendix

Proof of Proposition 1:

First, the following claim will be proved:

Claim 1 *In any equilibrium, there exists a* $y_1 \in [-1,0]$ *and a* $y_2 \in [0,1]$ *such that*

$$p_i^*(x_i) = \begin{cases} 1 & \text{if } \mid x_i \mid \geq \mid y_i \mid, \\ 0 & \text{otherwise,} \end{cases}$$

for $i = 1, 2$, $x_1 \in [-1, 0]$, *and* $x_2 \in [0, 1]$.

Proof of Claim 1: Let delegation schemes $p_i^*(\cdot)$, $i = 1, 2$, be given.
(i) Suppose that A_2 is uninformed, so that P_2 will select product location 1. If P_1's best response is to impose product location -1, then the proposition trivially holds. Therefore, suppose that P_1 optimally selects $p_1(\cdot)$ such that (1) holds. Accordingly, A_1 will get informed. Since $R_1(x_1, 1; h, \ell)$ is decreasing in x_1, there exists a $\tilde{y} \in (-1, 0]$ such that

$$R_1(x_1, 1; h, \ell) - R_1(-1, 1; \ell, \ell) \geq 0 \;\Leftrightarrow\; x_1 \leq \tilde{y}.$$

Two cases can be distinguished. First,

$$\int_{-1}^{\tilde{y}} p_1^*(x_1) \mathrm{d}x_1 \geq \frac{F}{\Delta}. \tag{8}$$

P_1's expected returns are equal to

$$\int_{-1}^{0} [p_1^*(x_1) R_1(x_1, 1; h, \ell) + (1 - p_1^*(x_1)) R_1(-1, 1; \ell, \ell)] \mathrm{d}x_1 =$$

$$\int_{-1}^{\tilde{y}} p_1^*(x_1)[R_1(x_1, 1; h, \ell) - R_1(-1, 1; \ell, \ell)] \mathrm{d}x_1 +$$

$$\int_{\tilde{y}}^{0} p_1^*(x_1)[R_1(x_1, 1; h, \ell) - R_1(-1, 1; \ell, \ell)] \mathrm{d}x_1 + R_1(-1, 1; \ell, \ell) \leq$$

(by monotonicity of R_1)

$$\int_{-1}^{\tilde{y}} [R_1(x_1, 1; h, \ell) - R_1(-1, 1; \ell, \ell)] \mathrm{d}x_1 + R_1(-1, 1; \ell, \ell) =$$

$$\int_{-1}^{\tilde{y}} R_1(x_1, 1; h, \ell)\mathrm{d}x_1 - \tilde{y}R_1(-1, 1; \ell, \ell).$$

It follows that P_1 can (weakly) increase his expected profits by selecting for $y_1 = \tilde{y}$,

$$p_1(x_1) = \begin{cases} 1 & \text{if } x_1 \leq y_1, \\ 0 & \text{otherwise.} \end{cases}$$

Second, it may be the case that

$$\int_{-1}^{\tilde{y}} p_1^*(x_1)\mathrm{d}x_1 < \frac{F}{\Delta}. \tag{9}$$

If

$$\int_{-1}^{\tilde{y}} 1 \,\mathrm{d}x_1 \geq \frac{F}{\Delta}, \tag{10}$$

then, by monotonicity of R_1, P_1 can increase his expected profits by selecting for $y_1 = \tilde{y}$,

$$p_1(x_1) = \begin{cases} 1 & \text{if } x_1 \leq y_1, \\ 0 & \text{otherwise.} \end{cases}$$

Now suppose that (10) does not hold. Let $\hat{y} \in (\tilde{y}, 0]$ be implicitly defined by

$$\int_{-1}^{\hat{y}} p_1^*(x_1)\mathrm{d}x_1 = \frac{F}{\Delta}.$$

Note that by (9), $\hat{y}$ is well defined. P_1's expected returns are equal to

$$\int_{-1}^{0} [p_1^*(x_1)R_1(x_1, 1; h, \ell) + (1 - p_1^*(x_1))R_1(-1, 1; \ell, \ell)]\mathrm{d}x_1 =$$

$$\int_{-1}^{\tilde{y}} p_1^*(x_1)[R_1(x_1, 1; h, \ell) - R_1(-1, 1; \ell, \ell)]\mathrm{d}x_1 +$$

$$\int_{\tilde{y}}^{\hat{y}} p_1^*(x_1)[R_1(x_1, 1; h, \ell) - R_1(-1, 1; \ell, \ell)]\mathrm{d}x_1 +$$

$$\int_{\hat{y}}^{0} p_1^*(x_1)[R_1(x_1, 1; h, \ell) - R_1(-1, 1; \ell, \ell)]\mathrm{d}x_1 + R_1(-1, 1; \ell, \ell) \leq$$

(by monotonicity of R_1)

$$\int_{-1}^{\tilde{y}} [R_1(x_1, 1; h, \ell) - R_1(-1, 1; \ell, \ell)]\mathrm{d}x_1 +$$

$$\int_{\tilde{y}}^{\hat{y}} p_1^*(x_1)[R_1(x_1,1;h,\ell) - R_1(-1,1;\ell,\ell)]\mathrm{d}x_1 + R_1(-1,1;\ell,\ell) \leq$$

(by monotonicity of R_1)

$$\int_{-1}^{y_1} [R_1(x_1,1;h,\ell) - R_1(-1,1;\ell,\ell)]\mathrm{d}x_1 + R_1(-1,1;\ell,\ell) =$$

$$\int_{-1}^{y_1} R_1(x_1,1;h,\ell)\mathrm{d}x_1 - y_1 R_1(-1,1;\ell,\ell),$$

where $y_1 \in (\tilde{y}, \hat{y}]$ is defined by

$$\int_{-1}^{y_1} 1 \, \mathrm{d}x_1 = \frac{F}{\Delta}.$$

It follows that P_1 can (weakly) increase his expected profits by selecting

$$p_1(x_1) = \begin{cases} 1 & \text{if } x_1 \leq y_1, \\ 0 & \text{otherwise.} \end{cases}$$

(ii) The proof of the case in which A_2 learns his private benefits is similar to case (i), and is omitted. □

Claim 1 allows us to define the level of discretion of agent A_1 as the measure of interval $[-1, y_1]$, that is, $X_1 \equiv y_1 + 1$, and similarly, A_2's level of discretion as the measure of $[y_2, 1]$, that is, $X_2 \equiv 1 - y_2$. This completes the proof. □

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Chapter 6

Aftermarkets: The Monopoly Case

6.1 Introduction

After-sales repair services and replacement parts are of major economic importance in many industries. Consider, for instance, the car industry: "A typical dealership earns most money from servicing and parts; only 15% of its profits come from new car sales."[1] Moreover, prices of repair services and replacement parts often tend to be relatively high; Voortman (1993) contains an extensive list of examples. For instance, in the United States, constructing a car by purchasing all the necessary parts from retailers, ignoring assembly costs, costs three to eight times the price of a fully assembled car.[2]

In this chapter I study pricing behavior of a monopolist who sells a durable good, and also sells repair services or replacement parts if the good breaks down at a later point in time. The notion of an "aftermarket" plays a key role in the analysis.[3] According to Shapiro and

[1] *The Economist* (1994), p. 72.

[2] See Voortman (1993) and the references therein.

[3] The term "aftermarket" was presumably coined by the United States Supreme Court in the antitrust case Eastman Kodak Company v. Image Technical Services, Inc. et al., 112 S. Ct. 2072 (1992); see Voortman (1993) and Shapiro and

Teece (1994), an aftermarket is defined by sales of products and services (e.g. replacement parts and repair services), used together with a primary product (equipment), that take place at a point in time after the purchase of the primary product. Thus, aftermarkets arise if some relevant variables that concern future transactions are not pinned down in a contract at the time of purchase of equipment. Here, I will assume that contracts that specify future prices of repairs or parts cannot be written.

The relevance of the incomplete-contract assumption is stressed in a report by the European Consumer Law Group (1988), who study the "legal situation concerning after-sales services – *falling outside the product guarantees*" (p. 1; emphasis added). Moreover, the report argues that even if maintenance contracts are written, they may prove to be worthless for consumers (p. 15).

Taylor (1995) provides casual evidence that in the information technology industry, firms experience inefficiencies due to high aftermarket prices. "The drive to reduce costs [...] has been taken up, too, by manufacturers, suppliers and specialist vendors keen to distance themselves from a possible user backlash" (p. 1). For this reason, equipment sellers such as Compaq Computer and IBM try to design their systems to cut maintenance costs, whereas other firms contract out technical support.

I focus on three questions. First, which equipment price and repair price will the monopolist charge? In the spirit of arguments made by Williamson (1985), problems of opportunism may arise when the seller has a locked-in consumer in need of a repair. Second, how do these prices compare to the optimal prices if one allows for long-term contracts? Finally, since it turns out that there is a discrepancy between equilibrium prices in these two cases, are there ways for the monopolist to increase or restore efficiency? To answer the latter question, I focus on dual sourcing (inviting a competitor in the aftermarket) and leasing.

Teece (1994) for detailed discussions.

In the model there are overlapping generations of risk-averse consumers: young consumers have the possibility to use information about current repair prices to form expectations about future repair prices. In each period, a young consumer enters the market to buy equipment. With some probability, equipment is of inferior quality.[4] In that case, the good breaks dows after the use of one period. If this happens, he must have it repaired by (or purchase a replacement part from) the seller to use it again when he is old. I assume that a young consumer expects a future repair price equal to the repair price he observes when he enters the market to buy equipment.[5] This reputation mechanism allows the seller to instantaneously establish a reputation for not exploiting consumers in need of a repair.

The seller faces a tradeoff between decreasing the aftermarket price, which increases the willingness to pay of young consumers, and exploiting old consumers in need of a repair. A main result is, surprisingly, that in spite of the fact that the seller faces no obstacles whatsoever in establishing a reputation for not exploiting old consumers, he charges a relatively high repair price, possibly equal to consumers' willingness to pay for a repair service. This result is in sharp contrast with the equilibrium outcome if long-term contracts are possible. In that case, the seller would fully insure consumers by committing to carry out repair services at a zero fee. Also, the seller may cross-subsidize equipment purchases by selling at a price below cost. In the long-term contract case, the seller would cross-subsidize repair services.

If future repair prices cannot be written in a contract, dual sourcing by inviting an aftermarket competitor is a means to drive down the aftermarket price. In a given period, however, giving up profits from repair services and replacement parts is attractive only if the monopolist can invite a competitor from the next period onwards. The reason is that in that period, the possibility of exploiting old consumers by

[4]This is an exogeneous event. Ex ante, neither the seller nor consumers can identify inferior goods.

[5]Expectations are required to be fulfilled in equilibrium.

charging a high aftermarket price makes dual sourcing unattractive. However, if the seller can credibly announce that from the next period onwards, the aftermarket will be competitive, then young consumers are willing to pay a high price for equipment, and the seller has a last opportunity to charge a high aftermarket price.

Finally, leasing equipment to consumers yields first-best efficiency. The reason is that by leasing, durability of the good and risk of breakdown only matter for the monopolist; consumers do not bear any risk. Therefore, also leasing may help the seller to overcome his commitment problem. Moreover, the seller strictly prefers leasing to dual sourcing.

Voortman (1993) and Shapiro and Teece (1994) discuss in detail many issues that may arise in aftermarkets, but develop no formal theory. To the best of my knowledge, this paper is the first one to formally address aftermarkets – although preliminary, because I focus on a monopoly.

The literature on repair services in a complete contracting framework (see for instance Heal (1977) and Chen and Ross (1994)) does not address aftermarket issues. An important insight of that literature is that optimal warranties provide full insurance for risk-averse consumers – this outcome provides a useful benchmark for aftermarket situations.

Also related is the literature on consumer lock-in and switching costs, studying markets in which buyers make relationship-specific investments when complete contracts cannot be written. Firms, who cannot distinguish between old and new consumers, compete to attract consumers whom they can exploit later, that is, a firm sells a single good at a single price (see e.g. Klemperer (1990) and Farrell and Shapiro (1988)). Farrell and Shapiro (1989) assume that sellers can discriminate between new and locked-in consumers, and study the relationships between noncontractable quality, unobservability of switching costs, and contract length. The main difference with these articles is that in an aftermarket situation, a firm sells *different* goods (equipment and aftermarket good), each at another price.

Shepard (1987) shows that it may be optimal for a monopolist to license a new technology to competitors. Since licensing induces quality competition, it results in a credible quality commitment, and may therefore increase demand. By focusing on dual sourcing instead of licensing, Farrell and Gallini (1988) derive results similar to those of Shepard. In my paper, the general idea that dual sourcing is a means to credibly commit is applied to pricing problems in aftermarkets.

My results suggest a rationale for leasing which is different from the one suggested by Coase (1972), who raised the following problem. If a durable-goods monopolist charges a price above the competitive level, consumers who are willing to buy at this price rationally expect a price decrease shortly after their purchases, and therefore wait to buy. Coase argued that leasing, which has the effect of turning the monopolist into a seller of nondurable goods, may solve this commitment problem caused by intertemporal price discrimination. In my model, leasing helps the monopolist to overcome a commitment problem due to the possibility to exploit buyers of equipment in the future.

The model is presented in the next section. The results are derived and presented in section 6.3, and section 6.4 concludes the chapter. In an appendix, I demonstrate that the reputation mechanism is not the driving force behind the insights.

6.2 The Model

In each period $t = 0, 1, 2, \ldots$, a consumer enters the market and lives for 2 periods. In each period, a consumer has an inelastic demand for one unit of a durable good that is produced by a monopolist.[6]

With probability $\lambda \in (0, 1)$, the monopolist's production technology delivers an inferior product. An inferior good breaks down (or, depending on the context, some crucial part of the good breaks down)

[6] In Voortman (1993), the monopolist is also called Original Equipment Manufacturer (OEM).

after the use of one period. If a product is not inferior it lasts for two periods. The seller and consumers can only identify goods as inferior when they break down.

In case of a breakdown, a consumer can use it again in a second period only if it is repaired (or if he buys a replacement part). Repair services or replacement parts ("aftermarket goods") are provided by the seller. Consumers in need of a repair, however, have the option to repurchase the good instead of buying the aftermarket good.[7]

In period t, the monopolist charges a price $p_t \geq 0$ for the good, and a price $s_t \geq 0$ for the aftermarket good. These prices are chosen before the seller knows whether he will have to carry out any repair services. A consumer who enters the equipment market at time t observes prices p_t and s_t. Information about maintenance costs may be available in publications such as *Consumer Reports.* Let s^e_{t+1} denote the aftermarket price that is expected by a consumer entering at time t. Accordingly, the overlapping-generations structure of the model enables young consumers to use information about current repair prices to form expectations about future repair prices.

Consumers and the monopolist discount future benefits with a factor $\delta \in (0,1)$. The monopolist is risk-neutral and maximizes his expected profits. Consumers maximize expected utility. Each consumer has a strictly increasing utility function $U(\cdot)$ that is twice differentiable. Consumers are risk-averse, that is, $U(\cdot)$ is strictly concave. Suppose $U(x) > 0$ for all $x > 0$, $U(0) = 0$, and $U(x) < 0$ for all $x < 0$. When the good does not break down, the utility of a consumer who buys it at time t equals $U(r - p_t + \delta r)$, where $r > 0$ is a given constant. When it does break down, the utility of a consumer who purchases the aftermarket good equals $U(r - p_t + \delta(r - s_{t+1}))$.

The unit cost of producing the good is c_0, whereas repairing the good costs $c \geq 0$. The parameters satisfy $c < c_0$, that is, repairing

[7]The seller can distinguish old from young consumers only if an old consumer makes himself known by buying a repair service or a replacement part.

is less costly than producing a new product, or, producing a spare part is less costly than producing a complete product. Throughout the chapter, c_0 and c are assumed to be sufficiently small, and r is assumed to be sufficiently large, in order to guarantee that there exist prices such that the monopolist is willing to produce and consumers are willing to buy. In period t, profits from selling equipment are equal to $p_t - c_0$. Given that consumers in need of a repair will buy the aftermarket good, expected aftermarket profits are equal to $\lambda(s_t - c)$.

An important assumption of the model is that long-term contracts, specifying a future aftermarket price at the time of purchase of the good, cannot be written.[8] [9] As Shapiro and Teece (1994, p. 141) argue: "Consumers rarely arrange for all of their parts and service when they purchase a machine [...]". The focus of the analysis is the way in which the equipment market and the aftermarket are interlinked as a result of this contractual incompleteness, and how the resulting inefficiency can be overcome.

Remark: The model tries to capture that consumers purchasing equipment believe that the monopolist will be in the market for an additional period. The infinite time horizon is an appropriate way to capture this feature; in a finite-horizon model, consumers would perceive a well-defined last period. In any subgame perfect equilibrium when there is a finite horizon, the seller would charge $s = r$ in the final period; equipment and aftermarket prices in the predecessing periods would then follow from an unraveling argument.

[8] To have a benchmark, the case of long-term contracts will also be analyzed.

[9] As argued in the introduction, this assumption is quite realistic. It is beyond the scope of this chapter to address why contracts are incomplete. Possibly, because of moral hazard problems concerning maintenance at the side of consumers, sellers do not offer a guarantee for at least some part of the good. See, e.g., Cooper and Ross (1985) for an analysis of warranties and two-sided moral hazard.

6.3 Analysis

A subgame perfect equilibrium in stationary strategies will be characterized by prices p^* and s^*, as well as purchase decisions of consumers, and consumers' expectations about future repair prices. In equilibrium, expectations will be required to be fulfilled.

At the time of purchasing the original equipment, consumers do not know the seller's future aftermarket prices. In order to make a purchase decision, however, a buyer must form an expectation of tomorrow's maintenance costs. To enable the seller to influence consumers' beliefs in a plausible way, so that he can directly influence his reputation for good behavior in the aftermarket, I make the following assumption:

Assumption 1 (Reputation mechanism) *Consumers' expectations satisfy* $s^e_{t+1} = s_t$ *for all* $t = 1, 2, \ldots$.

By assumption 1, a consumer who enters the equipment market expects a future price for repair services equal to the price that he observes today. As a consequence, the monopolist's reputation for charging low repair prices in the future is determined by his current pricing behavior. Thus, assumption 1 explicitly models how the seller can directly influence his reputation.[10] Moreover, the monopolist has the ability to instantaneously establish a reputation for not exploiting consumers in the aftermarket. Notice that in a stationary equilibrium, these beliefs are automatically fulfilled.

The first result, presented in lemma 1, is that equilibrium prices will be such that if a good breaks down, a consumer will have it repaired, instead of buying a new good. Thus, although the seller cannot distinguish old from young consumers, consumers in need of a repair will make themselves known by purchasing the aftermarket good.

[10]In the appendix I show that the unique equilibrium outcome generated by the reputation mechanism is also obtained if one assumes more general beliefs and applies a plausible forward-induction argument.

Lemma 1 *In any equilibrium, $p_t > r$ and $s_t \leq r$ for all t, that is, a consumer in need of a repair buys the aftermarket good instead of repurchasing equipment.*

Proof: Suppose that the claim does not hold. Suppose that, in some period, $p_t \leq r$. If $s_t \leq p_t$ then $\lambda U(r - p_t + \delta(r - s^e_{t+1})) + (1-\lambda)U(r - p_t + \delta r) > 0$. Consequently, the seller can increase profits by increasing p_t. If $s_t > p_t$ then a consumer who needs a repair in period t will buy new equipment. Since $c < c_0$, the seller can increase profits by choosing s_t just below p_t. Therefore, it must be that $p_t > r$ for all t. If $s_t > r$ then consumers in need of a repair will neither repurchase, nor buy the aftermarket good. Therefore, the seller can increase profits by choosing $s_t \in (c, r]$, a contradiction. It follows that $s_t \leq r$. □

By lemma 1, and because equilibrium prices are assumed to be stationary, the monopolist's problem in any subgame starting in $t = 1, 2, \ldots$, can be written as[11]

$$\begin{aligned} \max_{p_t, s_t} \quad & p_t - c_0 + \lambda(s_t - c) \qquad (1) \\ \text{s.t.} \quad & \lambda U(r - p_t + \delta(r - s^e_{t+1})) + (1-\lambda)U(r - p_t + \delta r) \geq 0, \\ & p_t > r, \\ & s_t \leq r, \\ & s^e_{t+1} = s_t, \\ & s_t, p_t \geq 0. \end{aligned}$$

Lemma 1 allows us to introduce a useful definition. Let the function $\xi(s^e_{t+1})$ be defined as the equipment price $p_t = \xi(s^e_{t+1})$ that makes a consumer who enters the market at time t indifferent between purchasing and not purchasing, for a given expected aftermarket price $s^e_{t+1} \in [0, r]$. Equivalently,

$$\lambda U(r - \xi(s^e_{t+1}) + \delta(r - s^e_{t+1})) + (1-\lambda)U(r - \xi(s^e_{t+1}) + \delta r) = 0. \quad (2)$$

[11] In problem (1), it would be equivalent to maximize the sum of discounted per-period profits from t onwards.

In order to solve problem (1), it is useful to know more about $\xi(\cdot)$. Lemma 2 states some results that will be needed below. In particular, $\xi(s)$ is a decreasing function, that is, high maintenance costs reduce a consumer's willingness to pay for equipment.[12]

Lemma 2 *For all $s \geq 0$, $\xi(s)$ satisfies*
(i) $-\delta < \xi'(s) \leq -\lambda\delta$ (with strict inequality if $s > 0$), and
(ii) $\xi''(s) < 0$.

Proof: (i) Differentiating (2) and rewriting yields

$$\xi'(s) = -\delta\lambda \, \frac{U'(r - \xi(s) + \delta(r - s))}{\lambda U'(r - \xi(s) + \delta(r - s)) + (1 - \lambda)U'(r - \xi(s) + \delta r)} \, . \tag{3}$$

Define $A \equiv r - \xi(s) + \delta(r - s)$, and $B \equiv r - \xi(s) + \delta r$. Then $A = B$ if $s = 0$, and $A < B$ otherwise. Notice $U'(A) > 0$ and $U'(B) > 0$. Since $U(\cdot)$ is concave, $U'(A) = U'(B)$ if $s = 0$, and $U'(A) > U'(B)$ otherwise. First, since $U'(A) \geq \lambda U'(A) + (1 - \lambda)U'(B)$, it follows that $\xi'(s) \leq -\delta\lambda$, with strict inequality if $s > 0$. Second, since $\lambda U'(A) < \lambda U'(A) + (1 - \lambda)U'(B)$, we have $\xi'(s) > -\delta$.
(ii) Differentiating (3) yields that the sign of $\xi''(s)$ is equal to the sign of

$$\begin{aligned} -\delta\lambda \, \{&U''(A)(-\xi'(s) - \delta)[\lambda U'(A) + (1 - \lambda)U'(B)] \; - \\ &U'(A)[\lambda U''(A)(-\xi'(s) - \delta) + (1 - \lambda)U''(B)(-\xi'(s))] \, \}, \end{aligned}$$

which can be written as

$$-\delta\lambda \, [U''(A)(-\xi'(s) - \delta)(1 - \lambda)U'(B) - U'(A)(1 - \lambda)U''(B)(-\xi'(s))].$$

Since $U(\cdot)$ is concave and strictly increasing, and $-\delta < \xi'(s) < 0$, it follows that $\xi''(s) < 0$. □

Before giving the solution to problem (1), a definition is given. Given that $\lambda < \delta$, let $\bar{s}$ be defined by

$$\xi'(\bar{s}) = -\lambda. \tag{4}$$

[12]The assumptions on $U(\cdot)$ imply that $\xi(\cdot)$ is twice differentiable.

The first proposition states a central result:

Proposition 1 *Suppose that assumption 1 holds. There exists a unique equilibrium. In this equilibrium,*
(i) if $\lambda < \delta$ *then* $p^* = \xi(s^*)$ *and* $s^* = \min\{\bar{s}, r\} > 0$,
(ii) if $\lambda \geq \delta$ *then* $p^* = \xi(s^*)$ *and* $s^* = r > 0$.
The equilibrium outcome is inefficient.

Proof: Consider any period $t \geq 1$. The monopolist will fully extract any consumer's surplus, so that $p_t = \xi(s_t)$. In problem (1), the constraint $p_t > r$ automatically holds. To see this, notice that by definition (2), a young consumer is never willing to pay more than $\xi(r)$ for the equipment. If he buys at price $\xi(r)$, his expected utility is $0 = \lambda U(r - \xi(r)) + (1 - \lambda)U(r - \xi(r) + \delta r)$, which implies that $r - \xi(r) < 0$. Since $s_t \leq r$ (lemma 1) and $\xi(\cdot)$ is decreasing (lemma 2), it follows that $p_t = \xi(s_t) \geq \xi(r) > r$.
Substituting $p = \xi(s)$ into per-period profits in problem (1) yields that profits in period t equal $\Pi_t(s) \equiv \xi(s) - c_0 + \lambda(s - c)$. By lemma 2 (ii), $\Pi_t(s)$ is concave. Suppose first that $\lambda < \delta$. Then, profits are maximized by $s^* = \min\{\bar{s}, r\}$, where $\bar{s}$ satisfies the first-order condition $\Pi_t'(s) = \xi'(s) + \lambda = 0$. Second, if $\lambda \geq \delta$ then $\Pi_t'(s) = \xi'(s) + \lambda > 0$ for all s, so that profits are maximized by $s^* = r$. In both cases, the equipment price satisfies $p^* = \xi(s^*)$ (and also $p_0^* = \xi(s^*)$). Consumers' beliefs in equilibrium are $s_t^e = s^*$ for all t. The consumer who enters the market in period 0 rationally expects a future repair price s^*, and is willing to pay $\xi(s^*)$. Therefore, the equilibrium price in period 0 is also p^*.
In the case $\lambda < \delta$, it remains to be shown that $s^* > 0$ if $\bar{s} < r$. Suppose that $\bar{s} < r$ and $s^* = 0$, so that $A = B$ (where A and B are defined in the proof of lemma 1). Using (3), the first-order condition is then equivalent to $U'(A)(\delta - \lambda) = U'(B)(1 - \lambda)$. The latter equation implies $U'(A) > U'(B)$, which contradicts $A = B$.
An inefficiency arises because consumers, who are risk-averse, bear risk.

Finally, total profits from period t on are non-negative if and only if $(\xi(s^*) - c_0 + \lambda(s^* - c))/(1-\delta) \geq 0$, which is satisfied because marginal costs are assumed to be sufficiently small. □

Even though consumers' expectations as given by assumption 1 allow the seller to instantaneously build up a reputation for not exploiting consumers who need parts and service, by proposition 1 he charges a relatively high aftermarket price. The equilibrium prices reflect the seller's tradeoff between "insuring" young, risk-averse consumers against the risk of breakdown, and exploiting old consumers in the aftermarket.

Notice that it is possible that $p^* = \xi(s^*) < c_0$; in this case, the seller cross-subsidizes equipment purchases. Since high prices are charged on the aftermarket, however, the monopolist is willing to suffer losses on the equipment market. Hence it is possible that the seller has no market power in the equipment market, and charges a high markup in the aftermarket.

What is the effect of a marginal increase in λ on the equilibrium prices? Suppose that $\lambda < \delta$ and $s^* = \bar{s} < r$, where $\bar{s}$ is defined by (4). Differentiating (4) and applying lemma 2 yields that

$$\frac{\mathrm{d}s^*}{\mathrm{d}\lambda} = \frac{-1}{\xi''(s^*)} > 0.$$

Accordingly, the optimal aftermarket price is increasing in the probability of breakdown. As a consequence,

$$\frac{\mathrm{d}p^*}{\mathrm{d}\lambda} = \xi'(s^*)\,\frac{\mathrm{d}s^*}{\mathrm{d}\lambda} < 0,$$

that is, the equipment price is decreasing in the probability of breakdown.

Williamson (1985) emphasized that in relationships in which parties make irreversible investments, contractual incompleteness may lead to underinvestment. In my model, a young consumer invests in a specific asset, that is, he purchases equipment, and the seller chooses ex post the price of the aftermarket good, which is noncontractable ex ante.

Since it is possible that $s^* = r$, the reputation mechanism specified in assumption 1 may be ineffective in alleviating the "hold-up" problem of exploiting consumers in need of a repair.

To view proposition 1 in perspective, it is useful to consider the case in which long-term contracts can be written.

Proposition 2 *Suppose that long-term contracts are possible. There exists a unique equilibrium. In this equilibrium, $\hat{p} = r(1+\delta)$ and $\hat{s} = 0$. The equilibrium outcome is efficient.*

Proof: Using long-term contracts, in every period t the monopolist chooses p and s such that $p = \xi(s)$, and s maximizes $\Pi_t(s) \equiv \xi(s) - c_0 + \delta\lambda(s - c)$. By lemma 2, $\Pi_t(\cdot)$ is a concave function. Its derivative satisfies $\Pi_t'(s) = \xi'(s) + \delta\lambda = 0$ if $s = 0$ and $\Pi_t'(s) < 0$ otherwise. Therefore, the monopolist will choose s as small as possible, so that $\hat{s} = 0$. Moreover, from (2) it follows that $\hat{p} = \xi(\hat{s}) = r(1+\delta)$. The equilibrium outcome is efficient because the seller, who is risk-neutral, bears all the risk. $\square$

According to proposition 2, the seller would want to be able to commit himself to an aftermarket price as low as possible.[13] Since consumers are risk-averse, it would be efficient to offer consumers a complete insurance against equipment breakdown by performing repair services at no charge. Consumers then would pay for such an insurance via a higher equipment price.

It is interesting to notice that if long-term contracts can be written, the monopolist cross-subsidizes repair services if $c > 0$. This observation is in sharp contrast with the incomplete-contract case, in which the seller may cross-subsidize equipment purchases.

Example:

In this example, the results will be related to consumers' risk aver-

[13]See, for instance, Heal (1977) and Chen and Ross (1994) for similar results in different settings.

sion. Suppose that $U(x) = -e^{-ax} + 1$, where $a > 0$. The Arrow-Pratt measure of absolute risk aversion (defined as $-U''(x)/U'(x)$) is constant and equal to a. Assume that the parameters satisfy $\lambda < \delta$ and $r > \ln[(1-\lambda)/(\delta-\lambda)]/(a\delta)$. Using (2), one can calculate that $\xi(s) = r(1+\delta) - \ln(\lambda e^{a\delta s} + 1 - \lambda)/a$. Applying proposition 1, it follows that $s^* = \ln[(1-\lambda)/(\delta-\lambda)]/(a\delta)$, which can be used to calculate $p^* = \xi(s^*) = r(1+\delta) - \ln[\delta(1-\lambda)/(\delta-\lambda)]/a$. By defining $K(a) \equiv \ln[\delta(1-\lambda)/(\delta-\lambda)]/a$, one can write $p^* = \hat{p} - K(a)$. The Williamsonian "underinvestment" $K(a)$ can be interpreted as the decrease in willingness to pay compared to the first-best price $\hat{p} = r(1+\delta)$ (see proposition 2), when a consumer faces a risk of breakdown and subsequent "hold-up." The function $K(a)$ is decreasing so that the more risk-averse consumers are, the more young consumers are willing to pay. Repair price s^* is decreasing in a; if consumers become more risk-averse, the monopolist becomes more eager to (implicitly) insure consumers.

When a young consumer buys equipment, the seller would want to be able to commit himself to carry out repairs for free in the next period. Therefore, he may consider ways to drive down the aftermarket price, such as inviting an aftermarket competitor, or contracting out aftermarket goods to competing firms.

Suppose that there is an independent service organization (ISO), who can carry out repair services under identical conditions as the monopolist, but does not sell equipment. Initially, the seller's technology is proprietary, so that the ISO can enter the aftermarket only if the seller agrees. Suppose that in each period, the monopolist has the ability to grant the right to compete in the aftermarket from any future period onwards, possibly until infinity. The monopolist can inform consumers about dual sourcing without cost.

Abstracting from collusion, price competition results in an aftermarket price $s = c$ under dual sourcing. The optimal equipment price under dual sourcing is then $p = \xi(c)$.

Proposition 3 *Suppose that the monopolist can invite a competitor in the aftermarket. There exists a unique equilibrium. In this equilibrium, the monopolist creates a competitive aftermarket from period 1 onwards. If* $c > 0$*, the equilibrium outcome is inefficient.*

Proof: For completeness it will be shown that in each period, the monopolist has an incentive to create a competitive aftermarket only from the next period onwards, so that in equilibrium, a competitor will be invited in period 0 to enter in period 1. Suppose in some period $t = 1, 2, \ldots$, the monopolist grants the right to compete in the aftermarket from the next period onwards. Then consumers who enter in period t are willing to pay $\xi(c)$ for the good. Notice that in this case the seller can choose (only in period t) $s_t = r$. Therefore, dual sourcing from period $t+1$ onwards is optimal if and only if

$$\lambda(r-c) + \frac{\xi(c) - c_0}{1-\delta} \geq \frac{\xi(s^*) - c_0 + \lambda(s^* - c)}{1-\delta}, \tag{5}$$

where equilibrium prices without dual sourcing, $(\xi(s^*), s^*)$, are given in proposition 1. By the Mean Value Theorem, there exists an $\tilde{s} \in (c, s^*)$ such that $\xi'(\tilde{s}) = [\xi(s^*) - \xi(c)]/(s^* - c)$. Therefore, (5) holds if and only if there exists an $\tilde{s} \in (c, s^*)$ such that

$$\xi'(\tilde{s})(s^* - c) \leq \lambda(r-c)(1-\delta) - \lambda(s^* - c). \tag{6}$$

Notice that $\xi'(\tilde{s})(s^* - c) \leq \lambda(s^* - c)(1-\delta) - \lambda(s^* - c)$ is equivalent with $\xi'(\tilde{s}) \leq -\delta\lambda$, which is true by lemma 2. Therefore, $\xi'(\tilde{s})(s^* - c) \leq \lambda(s^* - c)(1-\delta) - \lambda(s^* - c) \leq \lambda(r-c)(1-\delta) - \lambda(s^* - c)$, so that (6) is satisfied.

Similarly, one can show that in period 0, it is optimal to invite a competitor from period 1 onwards if and only if there exists an $\tilde{s} \in (c, s^*)$ such that $\xi'(\tilde{s}) \leq -\delta\lambda$, which follows from lemma 2. Finally, in period 1 it is optimal to invite a competitor from period 1 onwards if and only if $(\xi(c) - c_0)/(1-\delta) \geq (\xi(s^*) - c_0 + \lambda(s^* - c))/(1-\delta)$, which holds if and only if there exists an $\tilde{s} \in (c, s^*)$ such that $\xi'(\tilde{s}) \leq -\lambda$. Using that $\xi'(\cdot)$ is decreasing (lemma 2) and $\xi'(s^*) \geq -\lambda$ (see the proof of proposition 1), one can show that such an $\tilde{s}$ does not exist. □

The interpretation of proposition 3 is as follows. Take the situation in which there is no competitor in the aftermarket as given. The monopolist then faces a tradeoff between creating a competitive aftermarket or not. In any period, however, the possibility of exploiting old consumers by charging a high aftermarket price makes dual sourcing in that period unattractive. Now suppose that in a given period, the seller can credibly announce that from the next period onwards, the aftermarket will be competitive. Then young consumers, and also future young consumers, are willing to pay a high price for equipment, and the seller still has a (last) opportunity to charge a high aftermarket price. Accordingly, only if the seller invites a competitor from the next period onwards dual sourcing is more profitable than sticking to a monopolistic aftermarket. Similarly, at date 0 there is not yet an established aftermarket, and the monopolist has an incentive to announce that from date 1 onwards, there will be a second source in the aftermarket.

As an extension of the model, and as another means to reduce the inefficiency caused by contractual incompleteness, it is interesting to consider the case in which the monopolist has the option to lease equipment to consumers, a contractual arrangement that was not allowed for in the model so far. Suppose that leasing occurs for single periods, so that lease contracts can be written even when long-term contracts are impossible.

If the good breaks down after being used for one period, the seller repairs it and leases it again. Thus the seller incurs any repair costs. After two periods, the good can no longer be used. Let the per-period rent be denoted by ℓ_t. Now one can show that leasing is more profitable than selling.

Proposition 4 *Suppose that leasing equipment to consumers is possible. There exists a unique equilibrium. In this equilibrium, the monopolist leases equipment at per-period rent* $\ell^* = r$. *The equilibrium* *outcome is efficient.*

Proof: Under leasing, the seller maximizes $\Pi_t^L(\ell_t) \equiv \ell_t - c_0 + \delta(\ell_{t+1} - \lambda c)$ subject to the constraints $U(r - \ell_t + \delta(r - \ell_{t+1}^e)) \geq 0$ and $0 \leq \ell_t \leq r$. In a stationary equilibrium, the monopolist extracts all consumer surplus if and only if $U(r - \ell + \delta(r - \ell)) = 0$, so that $\ell^* = r$. Recall that first-best profits under selling are equal to $\Pi_t(0) \equiv r(1 + \delta) - c_0 + \delta\lambda(0 - c)$ (proposition 2). Since $\Pi_t^L(r) = \Pi_t(0)$, leasing results in the same profits as in the case of full warranties. □

Proposition 4 provides a rationale for leasing goods that can break down before the end of their potential life-cycle. By leasing equipment, the seller circumvents his commitment problem by acting as a seller of nondurable goods. Young consumers rent the good for one period, and whether or not the good breaks down after use, return it. The seller then repairs the good if necessary, and old consumers rent the good again. The optimal rent is equal to consumers' per-period reservation price for the good. Since the seller incurs any repair costs, consumers face no risk and the equilibrium outcome is efficient. Note that in order to obtain the efficient outcome by leasing, the seller does not have to be able to discriminate between young and old consumers.

If one compares dual sourcing and leasing, two differences are noteworthy. First, a corollary of propositions 3 and 4 is that, except if the marginal cost of repairing is zero, leasing is more profitable than dual sourcing. Second, whereas by dual sourcing the monopolist tries to mimic the first-best contract by decreasing the aftermarket price, leasing leads to a high aftermarket price.

6.4 Conclusion

The analysis in this chapter showed that a monopolist who sells a durable good that can break down, charges an inefficiently high repair price if long-term contracts (specifying future repair prices at the time of purchase) cannot be written. Inviting a competitor in the aftermarket (dual sourcing) increases efficiency because it results in competitive repair prices. By leasing the good instead of selling, durability of the good and risk of breakdown no longer matter for consumers; the monopolist bears all the risk so that efficiency is restored.

The results on dual sourcing show that more competition does not always result in less market power. Under dual sourcing, there is fierce competition only in the aftermarket, and the monopolist may fully extract consumers' surplus in the equipment market. Therefore, although dual sourcing increases efficiency, it does not decrease the seller's market power. A necessary condition to prevent the seller from extracting consumers' surplus is that there is competition in both the equipment market and the aftermarket.

Some issues that are outside the scope of this chapter seem to be worthwhile to explore. An important question is whether competition among several "original equipment manufacturers" decreases the firms' market power, given that repairs can only be carried out by original sellers. Another interesting extension of the model would be to have the monopolist choose the probability of breakdown by having it exert effort that determines the quality of the good. If effort and quality are unobservable to consumers, equipment and repair prices could serve as signals. Also, one could compare the seller's incentives to reduce the probability of breakdown under different contractual and institutional arrangements, such as warranties, dual sourcing and leasing.

Appendix

This appendix demonstrates that the reputation mechanism specified in assumption 1 is not the driving force behind the results. Summarizing this appendix, it is shown below that

1 any equilibrium outcome generated by the reputation mechanism can also be obtained by assuming more general beliefs,

2 equilibrium outcomes supported by more general beliefs inhibit, by and large, a discrepancy with the first-best outcome just as in the analysis, and

3 the unique equilibrium outcome selected by the reputation mechanism is also obtained if one applies a forward-induction argument to equilibrium outcomes supported by more general beliefs.[14]

Suppose that assumption 1 is not imposed. Consider a stationary equilibrium with prices (p^*, s^*) such that $p^* = \xi(s^*)$, supported by the following beliefs:

$$s_{t+1}^e = \begin{cases} s^* & \text{if } (p_t, s_t) = (p^*, s^*), \\ r & \text{otherwise.} \end{cases} \tag{7}$$

These beliefs are chosen such that after a deviation by the monopolist at time t, the willingness to pay $\xi(s_{t+1}^e)$ of a consumer who enters the market is reduced as much as possible, that is, down to $\xi(r)$.

Obviously, the seller would be punished more severely if consumers would refuse to buy equipment after a deviation. However, if a consumer expects to gain from buying after a deviation, such a punishment is irrational, and does therefore not pose a credible threat. If one restricts attention to punishments that are individually rational for consumers, beliefs (7) punish the seller as much as possible after a deviation.

[14] On forward induction, see Van Damme (1989).

Distinguish two cases.

(a) $\xi'(r) \geq -\lambda$. Suppose that $s^* < r$. By lemma 2, per-period profits $\Pi_t(s^*) = \xi(s^*) - c_0 + \lambda(s^* - c) < \xi(r) - c_0 + \lambda(r - c)$. Consequently, the seller has an incentive to deviate with $(p, s) = (\xi(r), r)$. Therefore, there is a unique equilibrium outcome that is supported by beliefs (7); in this equilibrium, $(p^*, s^*) = (\xi(r), r)$. Accordingly, the reputation mechanism and beliefs (7) lead to the same equilibrium outcome.

(b) $\xi'(r) < -\lambda$. Define $\tilde{s} \equiv \max\{0, s'\}$, where $s' < r$ is defined by $\xi(s') - c_0 + \lambda(s' - c) = \xi(r) - c_0 + \lambda(r - c)$. Now any pair (p^*, s^*) with $p^* = \xi(s^*)$ and $s^* \in [\tilde{s}, r]$ can be supported by beliefs (7) in an equilibrium. The reputation mechanism, however, would lead to a unique equilibrium outcome $(\xi(\bar{s}), \bar{s})$, where $\bar{s} \in (\tilde{s}, r)$ maximizes per-period profits $\Pi_t(s)$; see definition (4). Typically $s^* > 0$ (although one can construct $s^* = 0$ if $\xi'(r) < \lambda$ and $\tilde{s} = 0$). Therefore, also in this case equilibrium outcomes supported by beliefs (7) exhibit, by and large, a discrepancy with profits in the first-best outcome $\hat{s} = 0$ (see proposition 2).

By applying a forward induction argument, one can show that in case (b), beliefs (7) and assumption 1 lead to the same, unique equilibrium outcome. To see this, suppose that $\xi'(r) < -\lambda$, and consider an equilibrium outcome $(p^*, s^*) = (\xi(s^*), s^*)$ supported by beliefs (7), such that $s^* \neq \bar{s}$. Suppose that in some period $t = 1, 2, \ldots$, the seller deviates by choosing $(p_t, s_t) = (\xi(\bar{s}), \bar{s})$. If instead of believing $s^e_{t+1} = r$, consumers would believe that $s^e_{t+1} = \bar{s}$, then by definition of $\bar{s}$, the seller's profits would be increased to a maximum. Accordingly, one might argue that consumers should interpret the deviation as a signal of the monopolist's intention to choose repair price $\bar{s}$ in the future.

Only the equilibrium outcome in which $(p^*, s^*) = (\xi(\bar{s}), \bar{s})$, which is the monopolist's most preferred outcome, is robust to this forward induction argument. Notice that this is the same equilibrium outcome as obtained under assumption 1. Therefore, by applying a forward-induction argument, the reputation mechanism and beliefs (7) lead to the same, unique equilibrium outcome.

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Summary in Dutch

Dit proefschrift bestaat uit vijf essays in de theorie van industriële organisatie en strategisch management. De analyses in de papers zijn gebaseerd op speltheoretische modellen.

Hoofdstuk 1, de inleiding, geeft een korte beschrijving van speltheorie, industriële organisatie en strategisch management, en presenteert elk van de essays aan de hand van een voorbeeld.

Hoofdstuk 2, "*Moral Hazard and Noisy Information Disclosure,*" bestudeert het strategisch vrijgeven van informatie in een spel waarin speler 1 (de "verzender") een boodschap kan verzenden naar speler 2 (de "ontvanger"). De informatie in zo'n boodschap betreft welke actie speler 1 kiest. Speler 2 kan de actie van speler 1 niet waarnemen. Een "actie" is bijvoorbeeld (de mate van) hard werken. Een veronderstelling in het model is dat ontvangen boodschappen direct verifiëerbaar zijn, zodat speler 1 als hij een boodschap verzendt niet zal liegen. Een andere veronderstelling betreft de aanwezigheid van ruis of communicatiestoornis: als speler 1 een boodschap verzendt is het mogelijk dat deze boodschap niet aankomt. Een voorbeeld is post die kwijtraakt. Nadat speler 1 een actie heeft gekozen en al dan niet een boodschap heeft verzonden, kiest speler 2 een actie op basis van de informatie die hij op dat moment heeft. Dat kan zijn: speler 2 weet niets (speler 1 verzond geen boodschap of door de ruis ging een boodschap verloren), of speler 2 weet welke actie speler 1 koos (speler 1 verzond een boodschap, en die kwam aan).

Het spel heeft een uniek evenwicht. Wanneer er voldoende ruis is (of de kosten van informatie verzenden zijn voldoende hoog) dan kiest speler 1 een lage actie en verzendt geen boodschap. Wanneer er weinig ruis is (en de kosten van informatie verzenden zijn voldoende laag) dan gebruikt speler 1 een gemengde strategie waarin hij met positieve kans een hoge actie kiest en speler 2 daarvan op de hoogte stelt via het verzenden van een boodschap, en met de complementaire kans een lage actie kiest en geen boodschap verzendt. Wanneer de kans dat een boodschap arriveert naar 1 convergeert, dan convergeert deze evenwichtsuitkomst naar de zogenaamde Stackelberg-uitkomst.

Hoofdstuk 3, "*Entry Deterrence and Signaling in Markets for Search Goods*," bestudeert toetreding van bedrijven in markten voor produkten of diensten met kwaliteitsonzekerheid. Een belangrijke veronderstelling is dat consumenten kwaliteit pas kunnen waarnemen wanneer ze (een winkel van) een bedrijf bezoeken en daar het produkt uitproberen alvorens tot eventuele aankoop over te gaan. In de markt bevindt zich reeds één gevestigd bedrijf, waarvan consumenten weten dat de kwaliteit laag is. Er is één mogelijke toetreder, waarvan de kwaliteit onzeker is voor consumenten. Deze twee bedrijven concurreren door gelijktijdig prijzen te kiezen voor hun produkten. Op basis van de waargenomen prijzen besluiten consumenten welk bedrijf ze zullen bezoeken. Indien een consument de toetreder bezoekt, kan hij kwaliteit waarnemen, en dan òf tot aankoop overgaan, òf kopen bij het gevestigd bedrijf, òf nergens kopen. Per veronderstelling brengt de tweede optie, overstappen naar het gevestigd bedrijf om daar te kopen, "bezoekkosten" met zich mee. Wanneer deze kosten laag zijn, dan kan de toetreder die hoge kwaliteit levert door het kiezen van een hoge prijs consumenten overtuigen dat hij inderdaad hoge kwaliteit levert. De reden is dat een consument die lage kwaliteit aantreft vanwege de hoge prijs bereid is om bij het gevestigd bedrijf te kopen in plaats van bij de toetreder.

In evenwicht is, grofweg gesproken, toetreding door een bedrijf dat hoge kwaliteit levert winstgevend wanneer bezoekkosten voldoende laag zijn. Een ander resultaat betreft gemeenschappelijke informatie onder de bedrijven. Wanneer het gevestigd bedrijf op de hoogte is van de kwaliteit van de toetreder en zijn prijs laat afhangen van deze informatie, dan is toetreding mogelijk onafhankelijk van de hoogte van de bezoekkosten. De reden is dat wanneer de prijs van het gevestigd bedrijf informatie verschaft over de toetreder aan consumenten, het gemakkelijker is voor de toetreder om consumenten te overtuigen van zijn kwaliteit.

Hoofdstuk 4, "*Delegation of Responsibility in Organizations*," bestudeert een hiërarchische relatie tussen een manager en een ondergeschikte. Een cruciale veronderstelling is dat de ondergeschikte harder zal werken naarmate hij meer *private benefits* kan realiseren. In de eerste plaats kan men hierbij denken aan plezier in het werk. Andere mogelijkheden zijn: het opdoen van ervaring, prestatiedrang, carrièremotieven, enzovoorts. De manager kan dan zijn ondergeschikte motiveren om hard te werken door hem meer vrijheid te geven, zodat de ondergeschikte tot op zekere hoogte zelf kan bepalen wat hij doet. Gegeven een situatie waarin gekozen moet worden uit een aantal projecten waarvan de ondergeschikte er één dient uit te voeren, kan de manager bepalen uit hoeveel van deze projecten de ondergeschikte zelf mag kiezen. De ondergeschikte kan dan uit deze deelverzameling een keuze maken op basis van zijn eigen voorkeur.

In het model maakt de manager de volgende afweging. Meer keuzevrijheid voor de ondergeschikte heeft als resultaat dat deze een grotere prikkel heeft om de projecten serieus te bekijken en vervolgens een voorstel te doen. Indien de manager dit voorstel accepteert dan zal de ondergeschikte hard werken – immers, de ondergeschikte zal een voorstel doen voor het project dat hij het liefst uitvoert. De keerzijde van het delegeren van verantwoordelijkheid is dat de manager minder invloed heeft op de projectkeuze.

De manager dient geloofwaardig te zijn wanneer hij zijn ondergeschikte laat kiezen; indien de ondergeschikte verwacht dat zijn voorstel geweigerd zal worden door de manager ondanks het feit dat de manager belooft dat dit project binnen de keuzevrijheid valt, dan zal de ondergeschikte niet gemotiveerd zijn om zijn keuzevrijheid te benutten. Eventuele problemen van geloofwaardigheid zijn op te lossen door de financiële structuur van het bedrijf aan te passen, bijvoorbeeld via het afsluiten van een financiëel contract met een derde partij.

Hoofdstuk 5, "*Strategic Delegation of Responsibility in Competing Firms*," bestudeert de impact van het delegeren van verantwoordelijkheid aan een ondergeschikte op de strategische marktpositie van een bedrijf. In het model zijn er twee met elkaar concurrerende bedrijven, elk bestaande uit een produkt manager en een middle manager. De bedrijven moeten bepalen welke produktvariant ze willen ontwikkelen en verkopen. Een produkt dat meer lijkt op het produkt van de concurrent leidt tot intensievere concurrentie en daardoor tot lagere winst. Een produkt in een zogenaamde "market niche" leidt daarentegen tot hogere winst. De produkt manager kan zijn ondergeschikte (die verantwoordelijk is voor ontwikkeling en produktie) opleggen wat de specificaties van een produkt moeten zijn, of zijn ondergeschikte tot op zekere hoogte zelf laten kiezen. Zoals in hoofdstuk 4 is de cruciale veronderstelling dat een middle manager harder zal werken naarmate hij meer *private benefits* kan realiseren.

In het model maakt een produkt manager de volgende afweging. Meer vrijheid voor zijn ondergeschikte vergroot de kans dat die een keuze kan maken die hem motiveert om hard te werken, zodat het produkt van hogere kwaliteit zal zijn. Meer vrijheid draagt echter het risico met zich mee dat de ondergeschikte kiest voor een produktspecificatie die leidt tot een produkt dat verder verwijderd is van de "market niche" die de manager in gedachten had. Dit leidt tot intensievere concurrentie en daardoor lagere winst. In het model worden Nash evenwichten afgeleid in het spel waarin de produkt managers beslissen hoeveel verantwoordelijkheid ze delegeren aan hun ondergeschikten.

Verder worden enkele implicaties voor strategisch management besproken. Keuzevrijheden voor ondergeschikten kunnen zowel strategische complementen als substituten zijn. Het delegeren van verantwoordelijkheid kan deel uitmaken van strategieën om toetreding af te schrikken, maar ook om toe te laten. De managementstijl van een produkt manager kan enerzijds door zijn ondergeschikte en anderzijds door concurrerende bedrijven volledig anders ervaren worden.

Hoofdstuk 6, "*Aftermarkets: The Monopoly Case*," bestudeert een monopolistisch bedrijf dat een duurzaam goed produceert en verkoopt, en repareert als er een defect optreedt. De cruciale veronderstelling is dat lange-termijn onderhoudscontracten niet opgesteld kunnen worden, zodat het bedrijf in iedere periode opnieuw kan bepalen hoeveel consumenten betalen voor een reparatie.

Uit het model volgt dat het bedrijf hoge reparatieprijzen kiest. Dit wordt veroorzaakt door het bestaan van oude klanten die mogelijk reparaties nodig hebben. Wanneer consumenten risico-avers zijn, is dit een inefficiënte situatie. Immers, indien er wèl onderhoudscontracten opgesteld konden worden, zou het bedrijf aanbieden om reparaties gratis uit te voeren. De reden dat deze strategie meer winst oplevert is dat consumenten die risico-avers zijn, bereid zijn meer te betalen voor het produkt wanneer ze bij aankoop er zeker van zijn dat ze in de toekomst geen dure reparaties hoeven uit te laten voeren. Lage reparatieprijzen kunnen beschouwd worden als een impliciete verzekering voor het door consumenten gelopen risico dat een produkt defect raakt.

Om te ontsnappen aan de inefficiëntie die onstaat wanneer onderhoudscontracten onmogelijk zijn kan de monopolist concurrentie in de reparatiemarkt uitnodigen. Wanneer onderhoudsbedrijven op prijs concurreren dan zal de reparatieprijs dalen, zodat consumenten minder risico lopen. Een andere manier om de inefficiëntie te elimineren is om het produkt te leasen in plaats van te verkopen. Wanneer leaseperioden kort zijn, dan kan een consument een defect produkt vervangen door een werkend produkt wanneer een lease-periode afloopt.

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STELLINGEN

bij het proefschrift

Essays in Industrial Organization and Management Strategy

Paul W.J. de Bijl

1

De keuze van Philips om met Digital Compact Cassette (DCC) compatibiliteit met de analoge Compact Cassette technologie te waarborgen, en de keuze van Sony om de concurrerende, niet-compatibele Mini Disc technologie te introduceren, vormen een Nash evenwicht waarin de bedrijven zich richten op verschillende marktsegmenten. (Zie De Bijl, P.W.J., en Goyal, S. (1995), "Technological Change in Markets with Network Externalities," *International Journal of Industrial Organization,* Vol. 13, pag. 307-325.)

2

De mate waarin een persoon of organisatie een inspanning levert die direct een andere partij ten goede komt neemt toe wanneer de kans dat die partij de geleverde inspanning (of verifieerbare informatie daarover) waarneemt groter wordt. (Zie hoofdstuk 2.)

3

De belangrijkste motivatie-factor in werk is plezier. (Hoofdstukken 4 en 5 nemen deze stelling, waarbij "plezier" ruimer opgevat wordt als *private benefits*, als uitgangspunt.)

4

De kans dat medewerkers van een bedrijf zich maximaal inzetten wordt groter naarmate zij meer invloed hebben op de strategiebepaling van de organisatie. (Zie hoofdstuk 4.)

5

Wanneer men een managementstijl omschrijft met de mate van "aardigheid" versus "hardheid" van een manager, kunnen de belevingen van managementstijl door enerzijds ondergeschikten en anderzijds concurrerende ondernemingen tegengesteld zijn. (Zie hoofdstuk 5.)

6

Deregulering en marktwerking zijn te rechtvaardigen vanuit het oogpunt dat elk individu een zekere verantwoordelijkheid draagt voor zijn of haar welzijn. (Zie *Financial Times*, "Adam Smith and the virtue of capitalism," 16 jan. 1995, pag. 12.)

7

De treinvertragingen veroorzaakt door de uitbreidingswerkzaamheden aan het spoorwegnetwerk kunnen dermate veel klanten wegjagen dat de uitbreidingen resulteren in overcapaciteit.

8

De discussie omtrent vrije nieuwsgaring bij voetbal kan vermeden worden door voetbalwedstrijden te beschouwen als commerciële TV-produkties met (a) voetballers als improviserende acteurs en (b) betalende kijkers.

9

Wanneer men in de etalage van een opticien niets ziet dat naar wens is, dan is men aan het goede adres.

PAUL DE BIJL studied
He carried out his PhD research at the CentER for Economic Research (Tilburg University) and at GREMAQ (University of Toulouse), within the framework of the European Doctoral Program ENTER. Currently he is a consultant at Science & Strategy, a strategy consulting firm in Utrecht.

This thesis contains five essays in the theory of industrial organization and management strategy. An introduction makes the main ideas accessible to non-specialists by presenting the essays as fictitious cases. The first essay investigates strategic disclosure of verifiable information. The disclosed information concerns a hidden action, and the transmission of information takes place in a noisy environment. The second essay explores how search costs and informational asymmetries influence the possibilities for entry in markets for search goods. The model that is used analyzes signaling with common information. The third essay presents a principal-agent model in which the agent enjoys working. The principal, instead of designing a pecuniary incentive scheme, can appeal to the agent's private benefits by giving him a say in the job the agent has to do. The fourth essay applies this idea in order to study the strategic impact of organizational structure. Possible linkages between internal organization and market strategy are highlighted. The last essay focuses on the prices selected by a monopolist who sells a durable good and repairs it in the case of breakdown. The monopolist can circumvent inefficiencies by inviting a competitor in the repair market or by leasing the good instead of selling it.

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